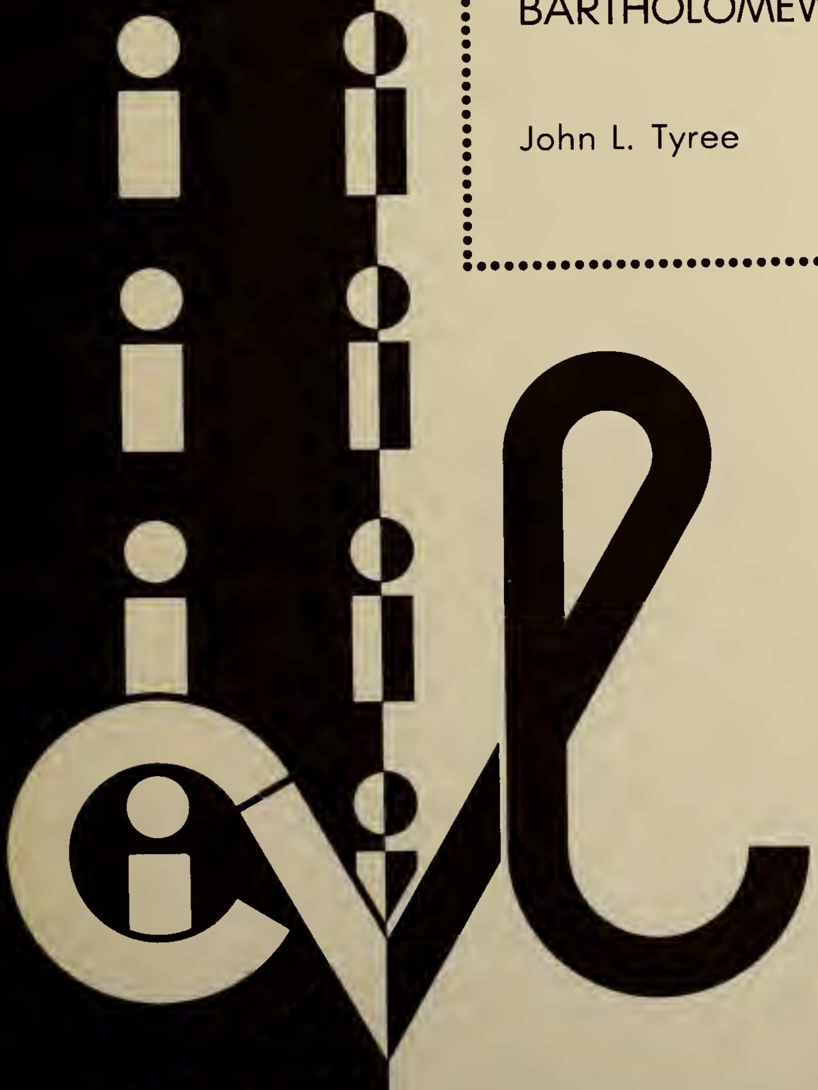
SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY
RESEARCH PROJECT
JHRP-86-6

ENGINEERING SOILS MAP OF BARTHOLOMEW COUNTY, INDIANA

John L. Tyree



PURDUE UNIVERSITY

Final Report

ENGINEERING SOILS MAP OF BARTHOLOMEW COUNTY, INDIANA

TO:	H. L. Michael, Director Joint Highway Research Project	March 27, 1986
		Project No: C-36-51B
FROM:	Robert D. Miles, Research Engineer Joint Highway Research Project	File: 1-5-2-78

The attached final report entitled "Engineering Soils Map of Bartholomew County, Indiana" completes a portion of the long-term project concerned with the development of a county engineering soils map of each of the 92 counties of the State of Indiana. This is the 78th report of the series. The report was prepared by John L. Tyree, Research Assistant, Joint Highway Research Project.

Mr. Tyree developed the engineering soils map using aerial photographs, available literature, available soil borings, and field studies. Generalized soil profiles of the major soils of each land form - parent material area are presented on the engineering soils map included. The map and report are useful in planning and developing engineered facilities in Bartholomew County.

Sincerely,

Robert D. Miles

Robert D. Miles, P.E.
Research Engineer

RDM/rrp

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Final Report

ENGINEERING SOILS MAP OF BARTHOLOMEW COUNTY, INDIANA

by

John L. Tyree
Research Assistant

Joint Highway Research Project
Project No.: C-36-51B
File No.: 1-5-2-78

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ENGINEERING SOILS MAP
OF
BARTHOLOMEW COUNTY, INDIANA

INTRODUCTION

The engineering soils map of Bartholomew County was prepared primarily by interpretation of aerial photographs. Accepted techniques of observation were used to delineate landform-parent material associations by stereoscopic inspection [1]. The aerial photographs used were taken for the U.S. Department of Agriculture in August 1939 and were purchased from the U.S.D.A. They were printed at a scale of 1:20,000 (1 mile = 3 inches).

The Agricultural Soil Survey of Bartholomew County [2] was used as a cross-reference to confirm soil boundaries. Several field trips were taken to the county to verify interpretations made from the aerial photographs. The text of this report includes a general description of the area, descriptions of the engineering soil types in the county, and a discussion of the engineering problems associated with the soils and bedrock in the county. Standard symbols developed by the staff of the Airphoto Interpretation Laboratory, School of Civil Engineering, Purdue University, were employed to distinguish landform-parent material associations and surface soil textures on the map. The shallow soil profiles of the different soil types were constructed from information obtained from the Bartholomew County Agricultural Soil Survey, field sampling, and borehole records.

DESCRIPTION OF THE AREA

General

Bartholomew County is located in south-central Indiana. The county is 21 miles wide in the east-west direction and varies from 15 miles to 21 miles in the north-south direction with the greater length on the western side. Part of the southern boundary is formed by Sand Creek. It has an area of 402 square miles (257,280 acres) and is bordered by six other counties: Johnson to the northwest, Brown to the west, Jackson to the southwest, Jennings to the southeast, Decatur to the east, and Shelby to the northeast (see Figure 1). The population was 65,088 in 1980. A summary of the populations of the cities in the county is given in Table 1.

Table 1. Population of cities in Bartholomew County [3]

City	Population 1980 Census	1970 Census	Population Change Difference	Percentage
Clifford	310	275	35	12.73
Columbus	30,292	26,457	3,835	14.50
Elizabethtown	603	519	84	16.18
Hartsville	379	434	-55	-12.67
Hope	2,185	1,603	582	36.31
Jonesville	213	202	11	5.45
Cities & Towns	33,982	29,490	4,492	15.23
Rural Areas	31,106	27,532	3,574	12.98
County Total	65,088	57,022	8,066	14.15

About two-thirds of the acreage of the county is used for crops. The steep areas within the glaciated parts of the county along with the sandstone and shale uplands are used for pasture

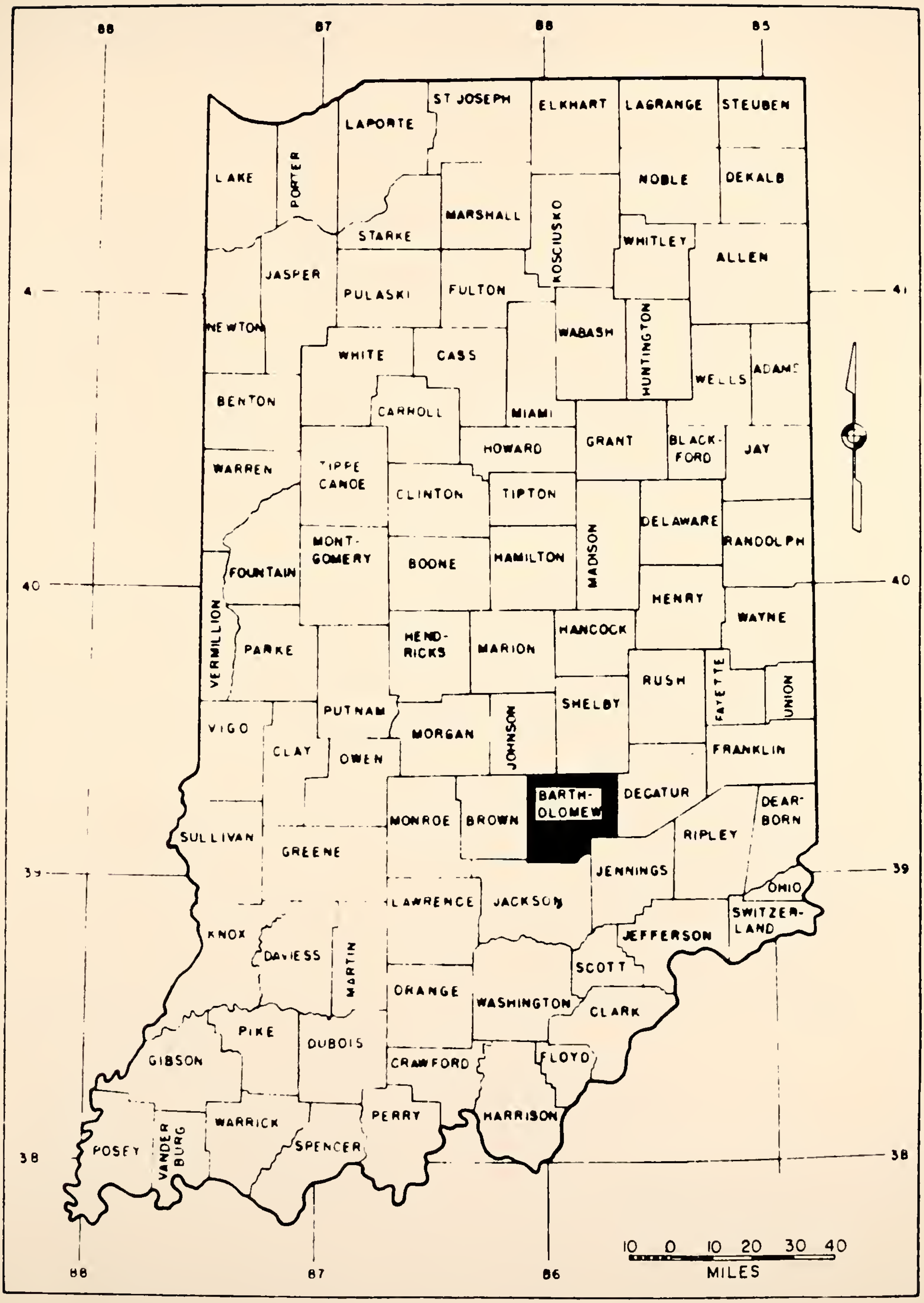


Figure 1. Location of Bartholomew County.

and woodland. The United States Air Force maintains a military reservation, Camp Atterbury, in the northwestern corner of the county.

Climate

The climate in Bartholomew County is humid and temperate with hot summers and cold winters. A climatological summary recorded at the Columbus station between 1934 and 1963 is given in Table 2. Temperatures have ranged from -17 degrees F to 111 degrees F during this period. The temperature exceeds 90 degrees F an average of 42 days per year while, on average, it remained below freezing 21 times per year.

Precipitation averaged 41 inches per year with slight increases in spring and slight decreases in the fall. Snowfall occurs only in the winter months averaging 11 inches per year. One out of five days the precipitation exceeds 0.1 inches.

Winds blow frequently from the southwest, however, in one or two of the winter months, prevailing winds are northwest. Only five tornados have been reported in the county since 1916. Thunderstorms occur about 48 days per year. Most of these occur in the spring and early summer and are seldom so severe as to cause loss of life, property, or crops.

Table 2. Climatological Summary of Bartholomew County (4).

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU
IN COOPERATION WITH PURDUE AGRICULTURAL EXPERIMENT STATION
CLIMATOGRAPHY OF THE UNITED STATES NO. 20 – 12

CLIMATOLOGICAL SUMMARY

LATITUDE 39° 12' N.
LONGITUDE 85° 55' W.
ELEV. (GROUND) 621 ft.

STATION COLUMBUS, INDIANA

MEANS AND EXTREMES FOR PERIOD 1934-1963

Month	Temperature (°F)							**	Precipitation Totals (inches)									Mean number of days					Month
	Means			Extremes				Mean degree days				Snow, Sleet					Precip .10 inch or more	Temperatures				
																		Max.		Min.		
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year		Mean	Greatest daily	Year	Mean	Maximum monthly	Year	Greatest daily	Year		90° and above	32° and below	32° and below	0° and below	
(a)	30	30		30		30		30	30	30		30	30		30		10	30	30	30	30	
Jan.	40.6	21.7	31.1	73	1943	-17	1936	1031	3.66	5.09	1949	3.1	8.8	1936	3.3	1939	8	0	8	26	2	Jan.
Feb.	43.6	23.3	33.6	72	1944+	-13	1951	880	2.83	2.29	1941	1.8	10.9	1936	6.0	1936	6	0	5	23	1	Feb.
Mar.	53.3	31.1	42.3	86	1939	-7	1960	722	4.03	3.66	1943	1.8	9.1	1937	6.0	1933	7	0	1	19	*	Mar.
Apr.	65.2	41.3	53.3	92	1937	20	1944+	368	3.83	2.66	1960	T	2.0	1953+	2.0	1953+	7	*	0	5	0	Apr.
May	76.0	51.0	63.5	98	1934	27	1947	130	4.26	4.53	1953	0	0		0		9	2	0	*	0	May
June	84.7	60.8	72.7	102	1936+	41	1956+	13	4.15	3.97	1960	0	0		0		7	9	0	0	0	June
July	88.6	63.7	76.1	111	1936	42	1947	0	3.42	3.36	1962	0	0		0		8	16	0	0	0	July
Aug.	87.3	61.8	74.7	106	1936	40	1946	6	3.33	3.32	1937	0	0		0		5	11	0	0	0	Aug.
Sept.	81.3	53.3	67.4	103	1939	30	1942	78	2.98	3.00	1956	0	0		0		6	6	0	*	0	Sept.
Oct.	71.1	42.8	57.0	92	1951	17	1952	279	3.32	2.77	1949	0.8	T	1962+	T	1962+	5	*	0	5	0	Oct.
Nov.	53.9	32.3	43.1	86	1950	-2	1950	651	3.20	2.30	1936	1.0	8.0	1950	8.0	1950	8	0	1	17	*	Nov.
Dec.	42.0	25.3	33.8	72	1951	-11	1963+	964	3.73	2.32	1949	2.9	11.8	1962	6.0	1962	5	0	6	25	1	Dec.
Year	63.8	42.2	53.0	111	July 1936	-17	Jan. 1936	5084	40.77	5.09	Jan. 1949	11.6	11.8	Dec. 1962	8.0	Nov. 1950	75	42	21	120	4	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F

+ Also on earlier dates, months, or years.

* Less than one half.

CLIMATE OF COLUMBUS, INDIANA

Columbus, located in Bartholomew County in Central Indiana, has an invigorating climate because of the frequent changes of the weather. Pleasant, cloudless days are interspersed with some rainy days throughout the year. Monsoon rains are unknown but rainfall is usually adequate in all seasons favoring a diversified agriculture. In the summer when moisture utilization is high, a dry month of below normal rainfall affects lawns, pastures, and crops.

Weather changes every few days come from the passing of weather fronts and associated centers of low and high air pressure. In general, a high brings lower temperatures, lower humidity and sunny days. An approaching low brings increasing temperatures, increasing southerly wind, higher humidity, and commencement of rain or showers. This activity is greatest in the spring and least in late summer and early fall.

Precipitation is rather evenly distributed throughout the year, a happy contrast to some areas of the United States that have a "dry season" and require irrigation to maintain green vegetation. The table of monthly rainfall for past years in this report shows the variation of rainfall that may be expected. There is a tendency for spring and early summer rains to exceed winter precipitation. The spring rains are very reliable insuring near maximum soil moisture going into summer when evaporation losses exceed rainfall and dry spells become more probable. A severe drought has never been experienced. About one-third of the annual rainfall flows into streams and out of the area. Future needs may require conservation of this water.

The probability for unusually heavy rains in just a few hours is indicated by a weather study of the area:

Frequency in 100 years	Rain in 1 hour	6 hours	12 hours
4	2.6	4.0	4.6
10	2.1	3.3	3.8
20	1.7	2.8	3.2

Snowfall has varied reception. None occurs in the summer. Some winters have much snow and others have very little. An occasional snow storm may hamper travel and clog roads but at the same time the snow blanket protects winter grains from the very cold air that invariably follows. Heaviest snow storms are those out of the southwest. As they swirl northeastward, abundant moisture flows in from the Gulf of Mexico. A storm out of the northwest, with an inward flow of colder, drier air, leaves less snow. Some midwinters are thus cold but snowfall is normal or less.

Relative humidity is not measured at this station but estimates are possible from the climatology of the area. Relative humidity varies on many summer days from a percent in the 40's in the early afternoon to the 90's about sunrise. Relative humidity rises and falls much as temperature does during a typical day but the highest percent usually occurs with the minimum temperature and the lowest percent with the maximum temperature. A cold front is next in importance in changing relative humidity downward.

Winds blow most frequently from the southwest, however, in one or two of the winter months, prevailing winds are northwest. Damaging winds have three sources. In the order of diminishing area coverage but increasing intensity, they are: lows passing through the region, thunderstorms, and tornadoes. Only 3 tornadoes have been reported in the county since 1916. Very few were of sufficient size to injure people and property. Thunderstorms, including incidences of lightning and thunder, occur about 46 days of the year. Most of these occur in the spring and early summer. They are seldom so severe as to cause loss of life, property, or crops. Death dealing smog or fog is unknown.

Heating degree days in the above table provide a comparative number for calculating heating requirements between different places and different times. Fuel consumption for heating is proportional to degree day totals, as a month with twice the heating degree days of another month requires twice as much fuel for heating. Degree days for a single day are obtained by subtracting the mean temperature from 65 degrees.

The growing season (defined here as the number of days between the last spring and first fall temperature of 32°) averages 167 days in length. The season is 189 days or more in 10% of the years, 178 days or more in 25% of the years, less than 156 days in 25% of the years, and less than 143 days in 10% of the years.

Many days of the year are nearly ideal in temperature. A few days, in the summer when temperatures exceed 90, or decline below zero in the winter, tend to obscure this fact. The fall season is considered by many as the best time of year for outdoor activities. Spring is also a favorite season but actually this season has more days of rain, and thunderstorms. In the fall the atmosphere in total seems more quiet. Air and soil temperatures are nearer in agreement than any other time of the year, thus, convective activity is diminished. Many days are sunny and showers are less frequent.

Lawrence A. Schaal
Weather Bureau State Climatologist
Purdue University, Agronomy Department
Lafayette, Indiana

Table 2. (Continued)

Average Temperature (°F)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

STATION HISTORY

[illegible]

[illegible]

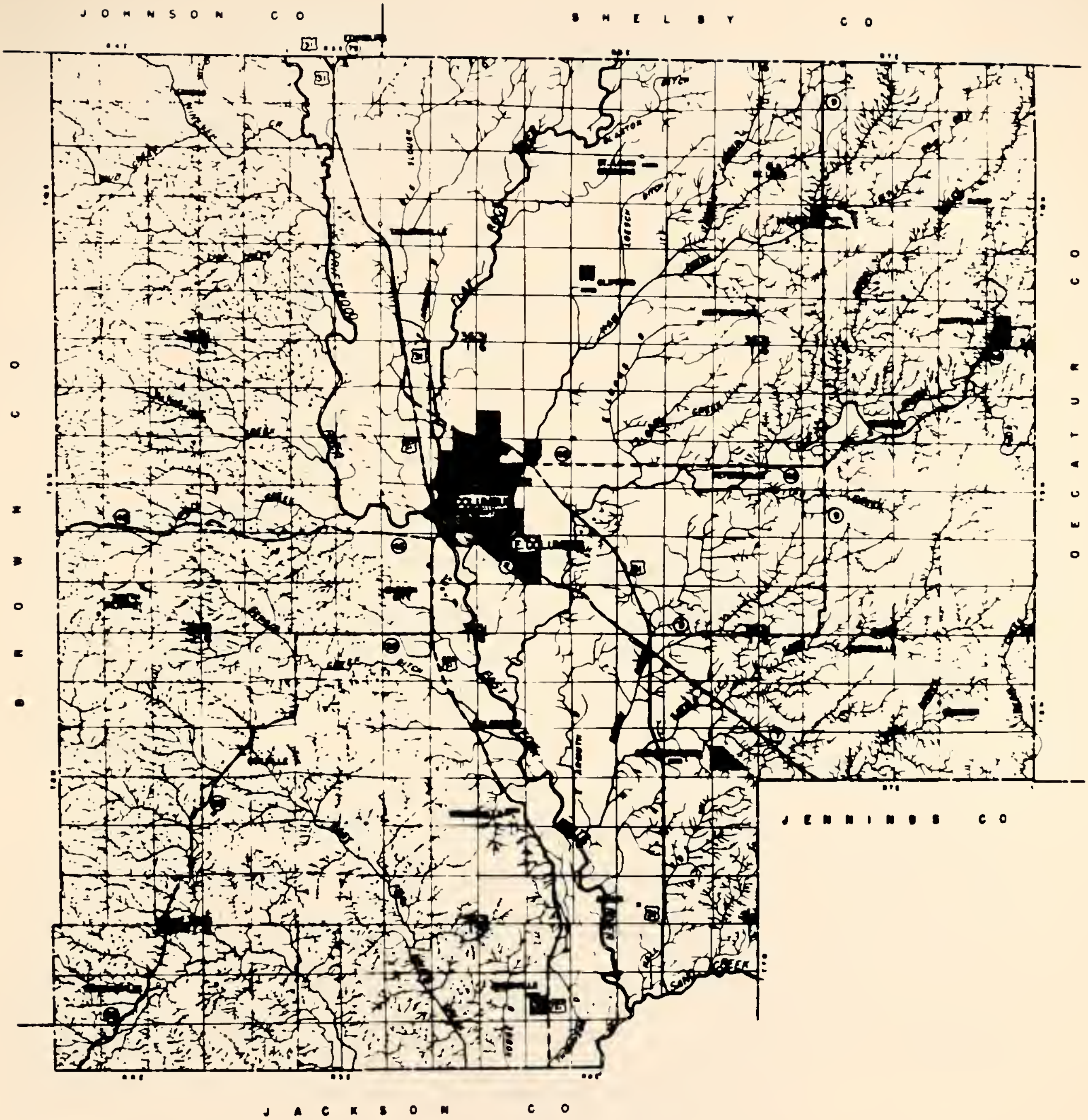
Total Precipitation (Inches)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Drainage

Bartholomew County is entirely included in the East Fork subdivision of the White River drainage basin. A drainage divide on the extreme western edge of the county causes a small area to drain towards the west into Salt Creek in Brown County. The rest of the streams in the county flow towards the main river systems in the middle of the county. The Driftwood River receives the runoff from the northwestern part of the county. The Flatrock River drains the northcentral part. The Driftwood River and the Flat Rock River join on the west side of Columbus to form the East Fork White River. The southwestern part of the county drains into the East Fork White River by several small watersheds with East Fork White Creek a major system. The eastern side of the county is drained by several systems to include Haw Creek, Clifty Creek, Little Sand Creek, and Sand Creek which all flow to East Fork White River in Bartholomew County. A drainage map of the county is shown in Figure 2.

The county has several distinctive drainage patterns. On the western edge of the county, sandstone and shale plateaus form steeply sloping stream valleys with a dense rectangular pattern. A little further east in the Illinoian till plain, the land has a highly dissected dendritic pattern. In the middle of the county streams are almost absent due to the highly porous nature of the underlying sand and gravel outwash deposits. In the eastern part of the county, in the Wisconsinan till plain, the pattern is again dendritic but much less dissected. Main tributaries are



DRAINAGE MAP
BARTHOLOMEW COUNTY
INDIANA

Figure 2. (5)

increasingly entrenched as one moves towards the east due to the preglacial valleys in the shallow limestone bedrock. Many streams east of the major rivers are `underfit´ meaning they are too small to have formed the broad valleys through which they now flow.

There are no natural lakes in Bartholomew County. Numerous man-made ponds and lakes are scattered throughout the county. These are used mainly for erosion control and recreation. Most of the larger lakes requiring earthen dams (up to 50 feet) are located in the western part of the county. Grandview Lake is the largest lake in the county (located in sec. 1,2,11,12, T.8N., R.4E.). A few man-made channels are required in some areas to supplement the natural drainage.

Physiography

Bartholomew County lies within three of the physiographic subsections of the Interior Low Plateaus Province of North America (see Figure 3). These three are from east to west: (1) the Muscatatuck Regional Slope, (2) the Scottsburg Lowland, and (3) the Norman Upland. Each physiographic subsection has general characteristics related to the bedrock geology.

The bedrock areas are overlain with significant accumulations of glacial, fluvial, and eolian deposits that form the Till Plain physiographic unit that extends over two thirds of the county. The Till Plain section includes Illinoian Till Plain, Wisconsinan Till Plain, and associated landforms.

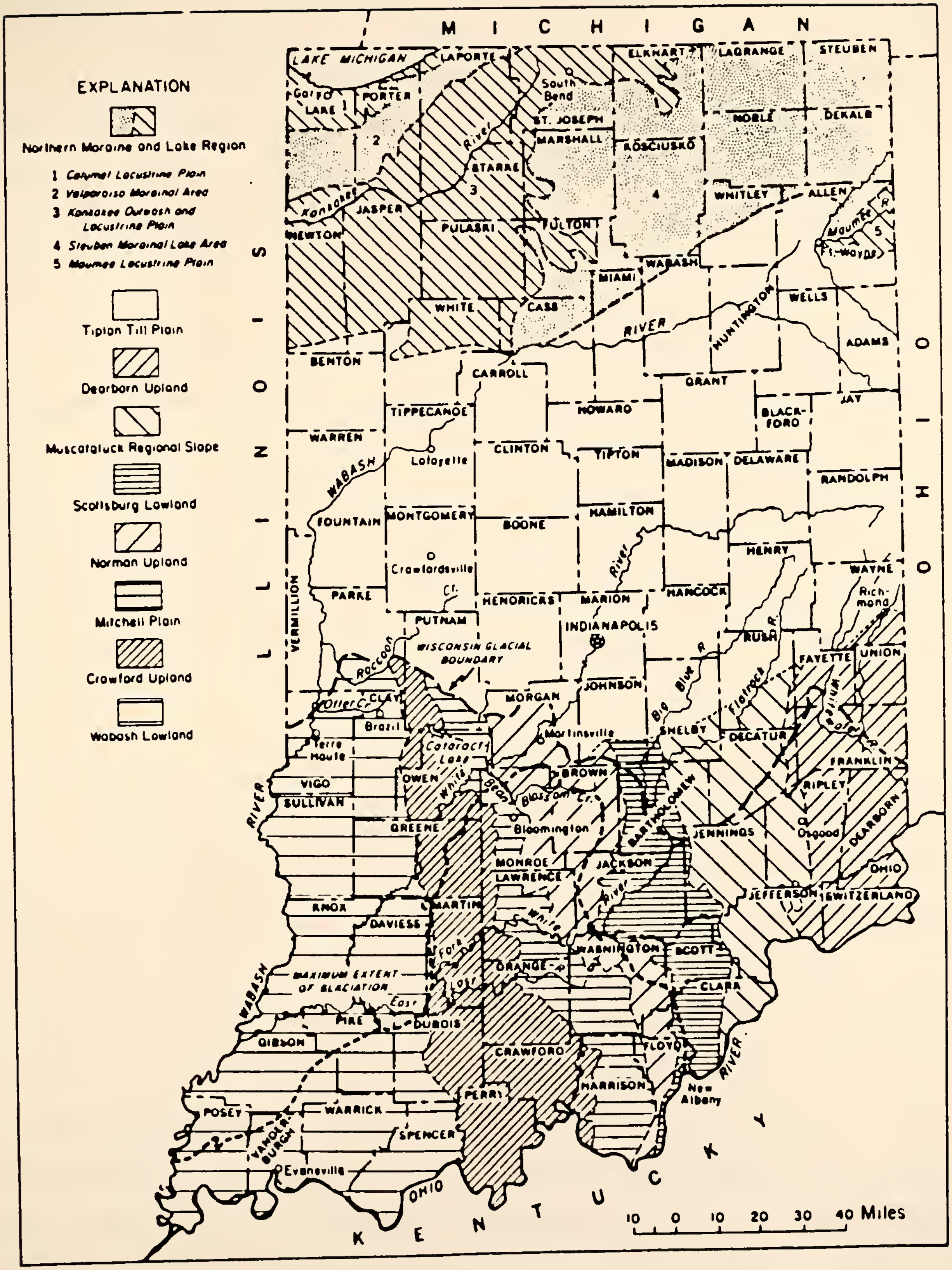


Figure 3. Map of Indiana Showing Physiographic Units and Glacial Boundaries. Modified from Indiana Geological Survey Report of Progress 7, figure 1 (35).

Topography

The topography of Bartholomew County is flat to very hilly. Wide flood plains and terraces, in the middle of the county, are flat and exhibit little in relief except near the break between the terrace and flood plain. Elevations range from 580 feet in the south to 700 feet in the north over a distance of 21 miles.

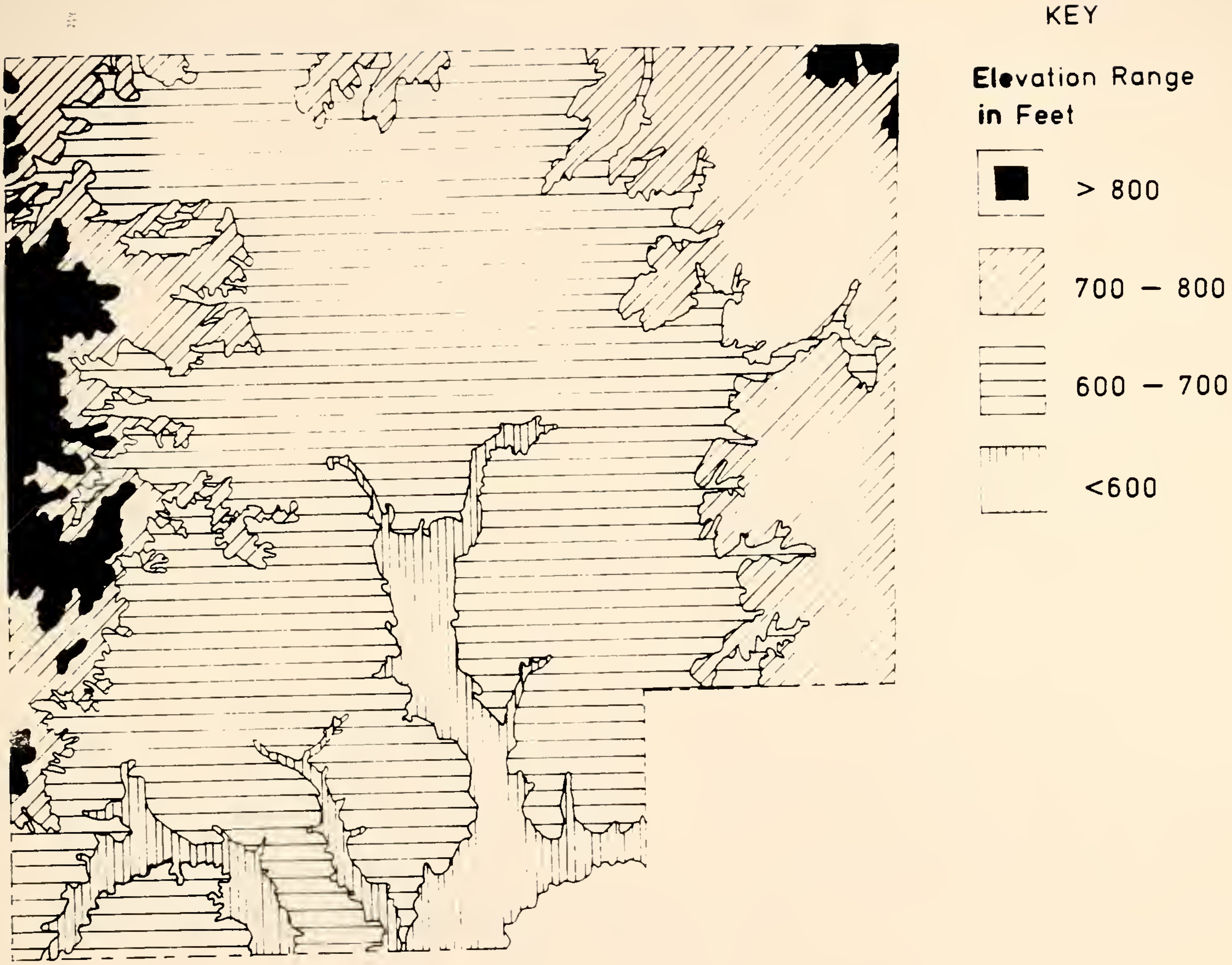
The area east of the main river valley (Flatrock River and East Fork White River) undulates gently on the Wisconsinan till plain and is broken occasionally by entrenched stream valleys which are 20 to 80 feet below the till plain. Regionally, the elevations decrease from 820 feet near the north-east corner of the county to 610 feet near the middle of the county. Locally, differences on the Wisconsinan till plain are 10 to 30 feet per half mile.

The area to the west of the main river valley (Driftwood River and East Fork White River) on the Illinoian till plain is flat to gently undulating and cut sharply by gullies and streams which are 20 to 60 feet below the till plain. The larger streams in this area have wide and flat flood plains. Regionally, the elevations increase from 600 feet near the East Fork White River to 750 feet at the bottom of the sandstone-shale plateau. Locally, elevations vary 10 to 20 feet per half mile. About two-thirds of this area is flat to gently undulating while the other third is the eroded sideslopes next to the gullies and streams.

The greatest relief is found on the western edge of the county in the Norman Upland. Elevations in this area, which extends about three to five miles east to west, are over 1000 feet above sea level compared to 580 feet, the lowest point in the county located on the East Fork White River where it exits the county to the south. Locally, elevations can differ as much as 200-300 feet from ridge top to valley bottom. Tributaries tend to be V-shaped while major valleys are U-shaped with wide, flat bottoms. Figure 4 is a topographic map of the county.

General Geology

The geology of Bartholomew County can be conveniently divided into two parts. The first is the bedrock of Paleozoic age and the second is the unconsolidated deposits of Quaternary and Recent age. Most of the bedrock is covered by unconsolidated deposits with the exception of the Norman Upland. Bedrock outcrops along the eroded valleys in the Muscatatuck Regional Slope, and a few small scattered remnants of bedrock occur within the Scottsburg Lowland.



Scale 1: 250,000 (1inch=4miles)
Contour interval= 100 feet

Figure 4. Topographic Map of Bartholomew County (6).

Bedrock Geology

Bartholomew County lies on the west flank of a regionally large anticline known as the Cincinnati Arch (see Figure 5). Rock strata are therefore dipping west-southwest at approximately 25 feet per mile. The relationship between the three physiographic subdivisions and the major underlying rock types (shale, limestone, etc.) is illustrated in Figure 6. Bartholomew County encompasses only the eastern middle third of the area shown. It can be seen that the Norman Upland is composed of the resistant sandstone - shale beds of the Locust Point Formation. The flatter physiographic subdivisions (Muscatatuck Regional Slope and Scottsburg Lowland) are composed of less resistant limestone and shale.

The bedrock geology is shown in Figure 7. Three rock systems are represented in the county: Mississippian, Devonian, and Silurian. Each system contains two or three formations which are listed in chronological order in Table 3 along with their respective thicknesses and lithologic descriptions.

The Locust Point Formation covers most of Brown County to the west and extends a few miles into Bartholomew County forming the resistant sandstone and shale plateau (Norman Upland). It is a variable formation with alternating beds of resistant sandstone and siltstone and degradable shale. In places the sandstone beds are sufficiently massive to have been quarried in the past [10]. The New Providence Shale occurs to the east of the sandstone-

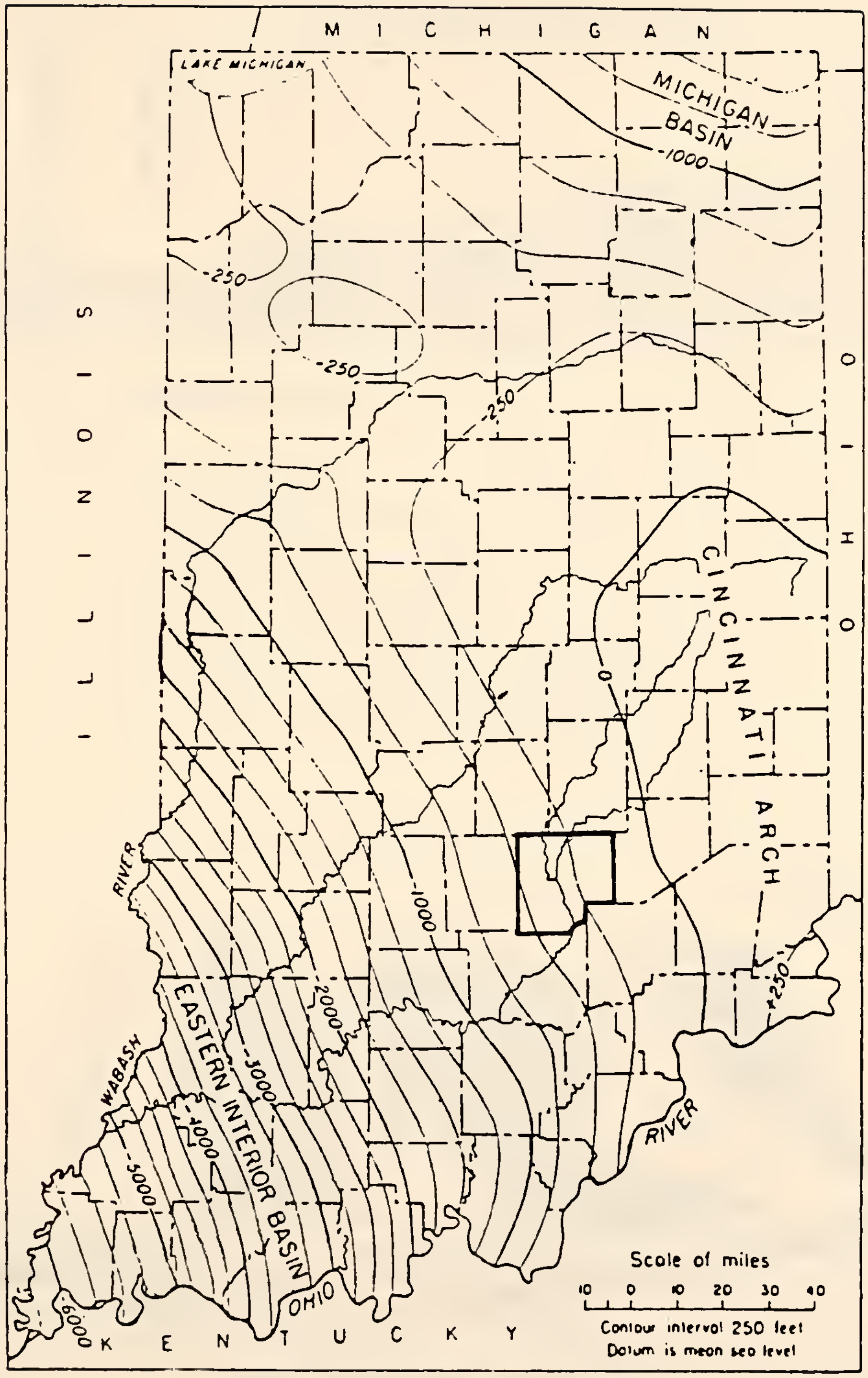
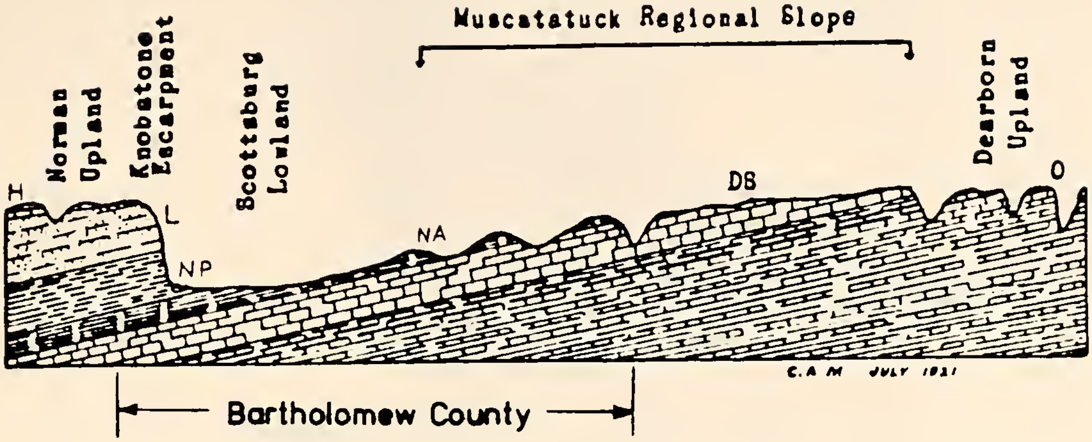
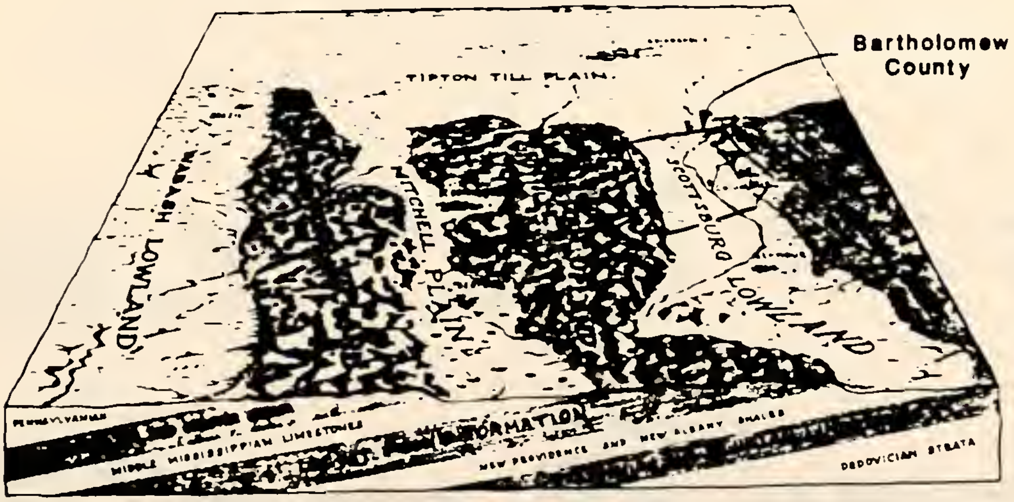


Figure 5. Bedrock Structure of Indiana. Contours Show Elevation of Top of Trenton Limestone (30).



East—West Cross—section (8).

H = Harrodsburg limestone
L = Locust Point Formation
NP = New Providence Shale
NA = New Albany Shale
DS = Devonian and Silurian limestones
O = Ordivician limestones and shales



East—West Block Section (7).

Figure 6. Geologic Cross—sections of the Physiographic Subdivisions in Bartholomew County (7 and 8).

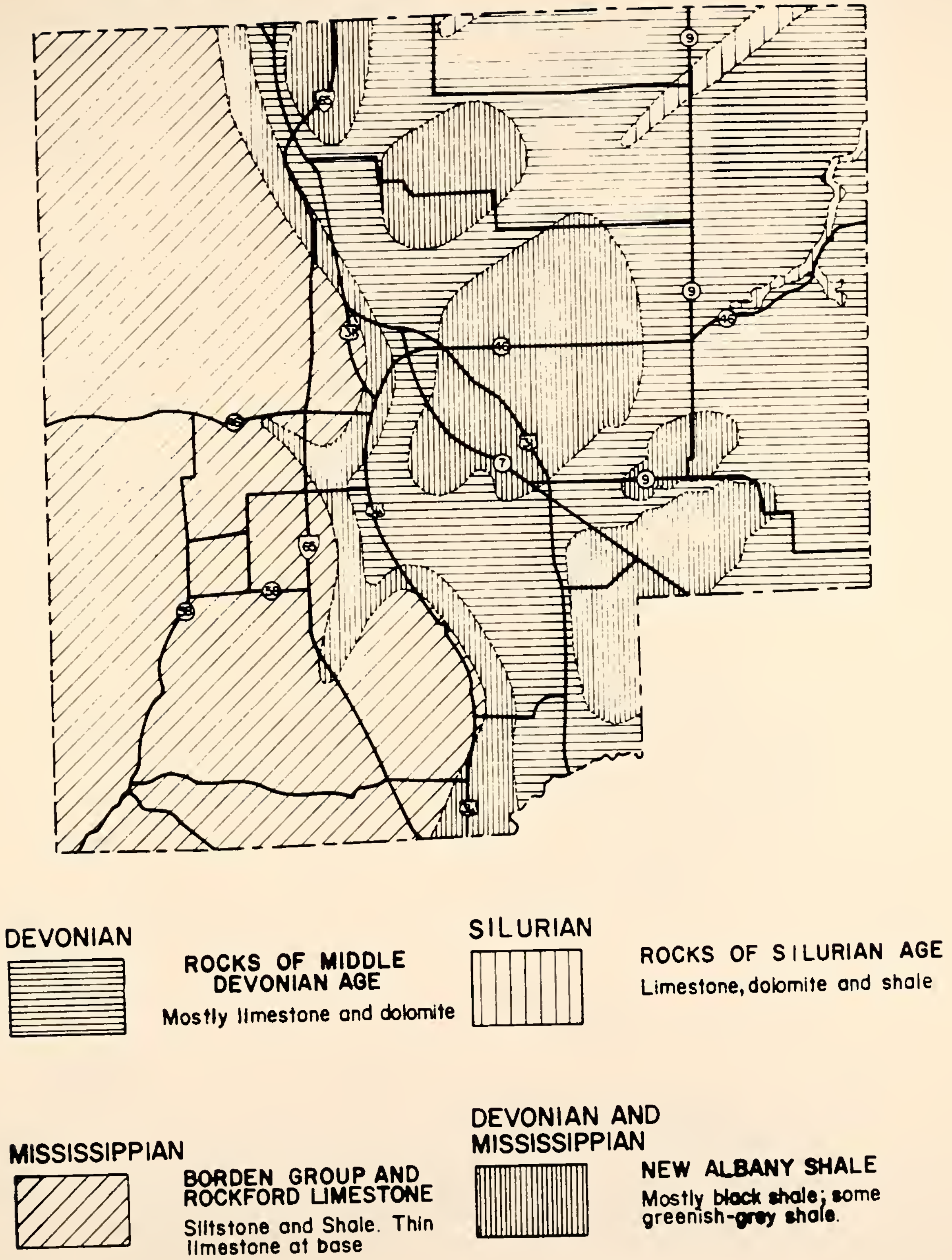

9
65
46
31
7
9
58
DEVONIAN
ROCKS OF MIDDLE DEVONIAN AGE
Mostly limestone and dolomite
SILURIAN
ROCKS OF SILURIAN AGE
Limestone, dolomite and shale
MISSISSIPPIAN
BORDEN GROUP AND ROCKFORD LIMESTONE
Siltstone and Shale. Thin limestone at base
DEVONIAN AND MISSISSIPPIAN
NEW ALBANY SHALE
Mostly black shale; some greenish-grey shale.

Figure 7. Bedrock Geology of Bartholomew County (11).

Table 3. Descriptions and Thicknesses of Bedrock Formations in Bartholomew County (9).

Age	Formation Name	Approximate Thickness (feet)	General Description
MISSISSIPPIAN	Locust Point Fm.	100-200´	alternating beds of resistant, gray siltstone, sandstone and soft, degradable shale
	New Providence Shale	up to(a) 290´	gray greenish-gray and reddish brown, soft, with thin limestones and bands of iron-carbonates, rapidly weathers to a plastic clay
	Rockford Limestone	5-10´	brownish-gray dolomitic limestone
	New Albany Shale	100-130´	gray and brown, evenly laminated, fissile, carbonaceous shale, weathers into thin plates
DEVONIAN	North Vernon Limestone	1-3´	gray coarsely crystalline, crinoidal limestone; solution cavities common
	Jeffersonville Limestone	35-80´	upper part is light-gray thickly stratified, fossiliferous limestone commonly containing solution features; lower part is tan to brown dolomitic limestone
	Geneva Dolomite	30-40´	brown crystalline dolomite; can be much thicker or thinner in places
SILURIAN	Wabash Formation	< 50´	gray, dolomitic siltstone, may not be present in the county
	Waldron Shale	< 10´(b)	varies from a gray calcareous(c) shale to a light green to bluish clay shale near Hartsville

(a) taken from "Compendium of Rock-Unit Stratigraphy in Indiana" [10].

(b) taken from "Handbook of Indiana Geology" [8].

(c) halfway between Newbern and Hartsville on Clifty Creek [8].

shale plateau at its base. It is a greenish-gray and reddish brown, soft clay shale that weathers rapidly with thin limestones and bands of iron carbonates parallel to the bedding. Outcrops are rare due to its Illinoian glacial till cover and high degradability upon exposure to the elements. The Rockford Limestone is a thin dolomitic limestone formation underlying the New Providence Shale and rarely outcrops due to the glacial till cover.

The next formation to the east is the New Albany Shale. Most of the Scottsburg Lowland is underlain by this shale. It is a black or gray-brown, evenly laminated, fissile, carbonaceous shale that weathers into thin plates. Currently the major rivers run directly over the New Albany Shale and it can be found outcropping in the flood plain of the Driftwood River.

An abrupt contact occurs between the New Albany Shale and the next formation, the North Vernon Limestone. This thin formation and the upper part of the underlying Jeffersonville Limestone are coarsely crystalline and fossiliferous and commonly contain solution cavities. The Jeffersonville Limestone becomes more and more dolomitic further down and gradually becomes the Geneva Dolomite. Three strips of Silurian formations along entrenched stream valleys stretch into the county from the east where they outcrop more extensively. It is unclear whether the Wabash Formation, a gray dolomitic siltstone is present in the county. The Waldron Shale has been recognized in several outcrops. It varies from a calcareous shale to a light green to bluish weak clay shale. Boreholes 4, 8, 33 to 37, 41, and 42

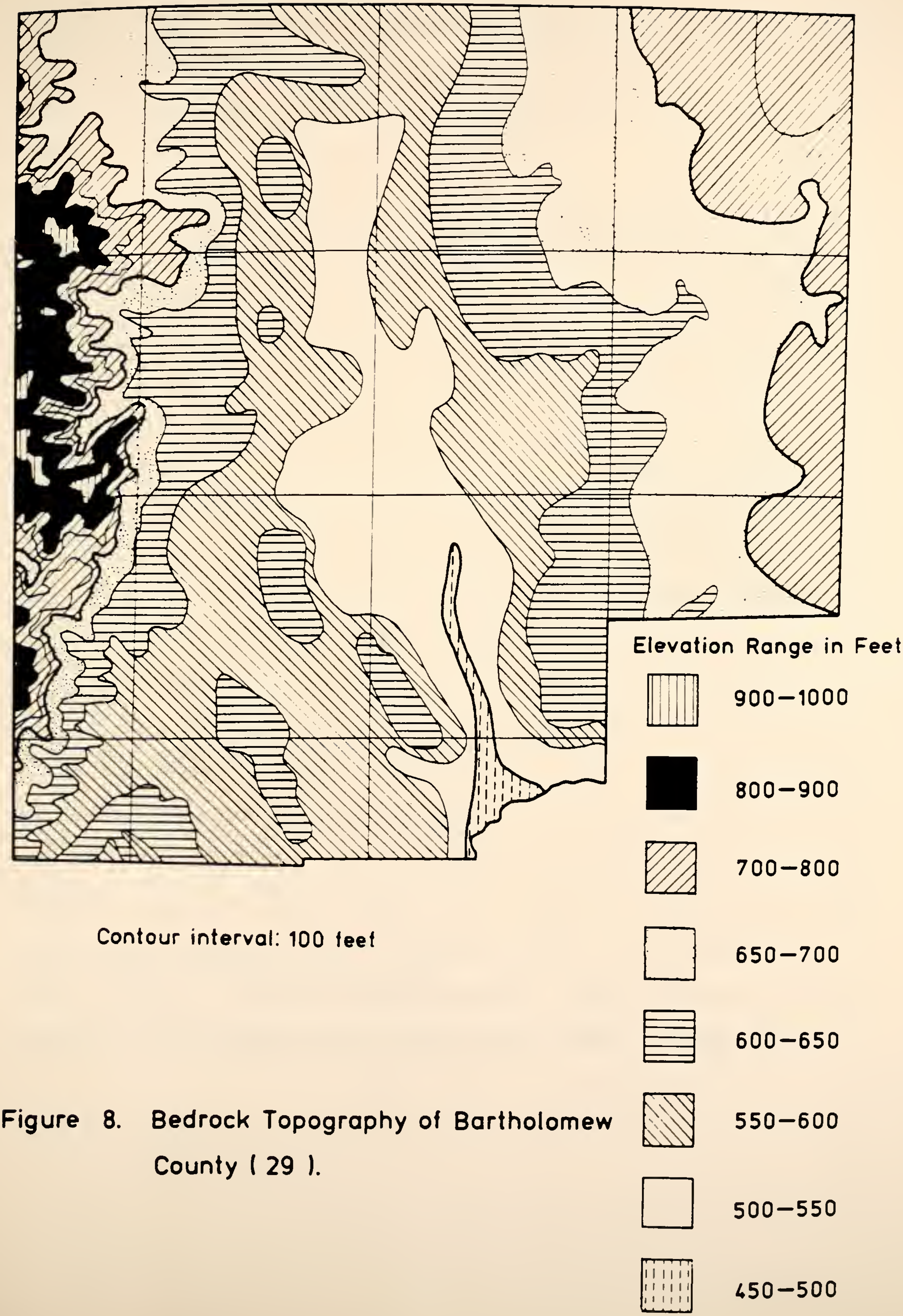
describe some of the rock formations encountered during drilling (see engineering soils map for location and Appendix A for descriptions).

The general topography of the bedrock surface is represented in Figure 8. This map was compiled using data from over two-hundred boreholes [40]. The sandstone - shale bedrock upland to the west is easily identified by its closely spaced contours while the rest of the county has a smoother surface. It is also important to note that the depth to bedrock is not always reflected by the surface topography.

Glacial Geology

Unconsolidated fluvial materials partially fill some bedrock valleys but the great bulk of the unconsolidated deposits are of glacial origin [8]. Only two of the four possible glaciation stages recognized in North America significantly affected Bartholomew County. These were the Illinoian and Wisconsinan glaciations, which followed the Nebraskan and Kansan glaciations. The extent of the Illinoian and Wisconsinan glaciations is illustrated in Figure 3.

The Illinoian glaciation occurred before the Wisconsinan glaciation and covered all of the county with ground moraine except for the elevated hills of the Norman Upland along the western boundary. The glacial till filled valleys and smoothed out the landscape but has subsequently been dissected by erosion. The western part of the county is covered by Illinoian till of



Contour interval: 100 feet

Figure 8. Bedrock Topography of Bartholomew County (29).

variable depth. Most of the eastern half of the county has Illinoian till covered by Wisconsinan till with the Wisconsinan till being roughly two or three times thicker than the Illinoian till [40].

Ice of the Wisconsinan glaciation did not cover the whole county. Wisconsinan till is found in the eastern half and the upper northwestern corner of the county. Some geologists previously had mapped terminal ridge moraines near the southernmost border of the glacial till but have subsequently changed that designation to simply ground moraine [8,11].

The melting associated with the retreat of the Wisconsinan ice left several landforms. Tremendous amounts of water flowed in tributaries and the major rivers. Meltwaters scoured the major river channels (over 100 feet) and redeposited sand and gravel outwash in the channels. These outwash deposits also extend laterally as much as 1 to 2 miles forming terraces which stand 5 to 20 feet above the present flood plains. Outwash extent and depth in the tributaries to the major rivers is also significant with one borehole showing as much as 50 feet. On the western side of the county the mouths of tributaries became dammed with sediment and ice causing lakes to be formed out of which silts, clays and sands settled. Some of these lacustrine deposits were eroded away as the stream eroded the dam but some

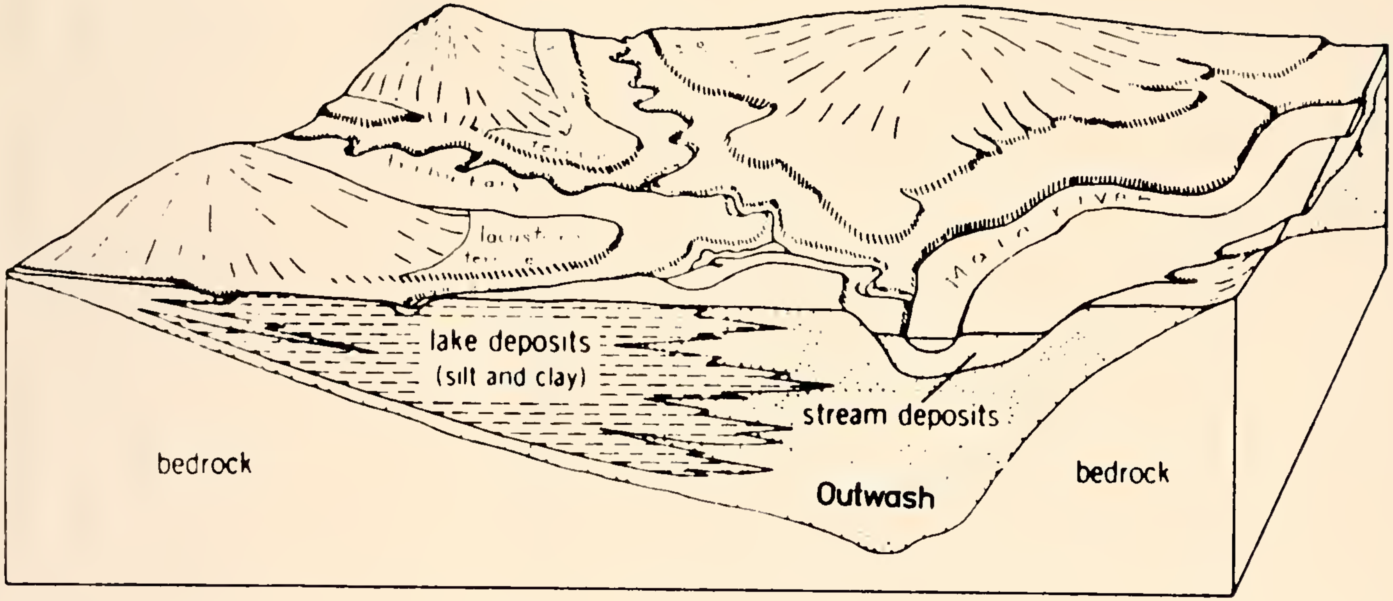


Figure 9. Block diagram showing relation of lake deposits to tributary valleys, glacial outwash (sand and gravel) in main valley, and associated stream deposits. Diagram does not show a specific place but incorporates many features typical of lake deposits and terraces that they form. Width of block about 10 miles; depth of block about 200 feet (12).

also remained and may be distributed as shown in Figure 9. The surficial expression of these deposits are small lacustrine terraces 1 to 15 feet above the tributary flood plain. The base of the deposit can extend much deeper than the surface of the adjacent flood plain.

Strong, unchecked winds blew sand from the flood plain and terraces up onto the edges of the till plains forming dunes. Most of the dunes formed on the east side of the East Fork White River suggesting the predominant winds were from the west. Silt sized particles (loess) were blown much further and in both directions. The flat hilltops of the Norman Upland are capped with a thin loess layer. These loess deposits although extensive are usually not greater than four feet and are usually less than two feet. They are also weathered and lacking some of the distinctive engineering properties of loess.

LANDFORMS AND ENGINEERING SOIL AREAS

Eolian Landforms

Loess Plain

A thin blanket of loess (wind blown silt) covers the entire county except for recent alluvial deposits and steep slopes where it has been eroded away. The loess is not considered thick or distinct enough to include as a separate unit on the engineering map but is worth mentioning here. Loess is thickest over the Illinoian ground moraine and the lacustrine terraces where it is

typically 2 to 4 feet. The sandstone-shale plateau has up to three feet of loess on the flat ridges and less on the sideslopes. The Wisconsinan ground moraine usually has less than two feet of loess cover.

The soils developed in loess are typically silt loam or silty clay loam (A-4 to A-6). The agricultural soil series which developed in loess are listed in Table 4 according to the parent material they overlie. The average loess thicknesses are given in parenthesis. The silty non-cohesive character of the loess makes it susceptible to highway performance problems. Highway subgrades and fills made of loess are subject to piping, pumping, and frost heave. Collapse of the natural soil structure upon wetting or leaching, as is common with other loess deposits, is expected to be much less severe since the loess is thin and weathered in most places.

Table 4. Agricultural Soil Series Formed Partially in Loess and the Underlying Parent Material in Bartholomew County [2].

Sandstone-shale	Illinoian ground moraine	Wisconsinan ground moraine	Lacustral terrace
Gilpin (<12")	Avonburg (24-48")	Celina (<18")	Dubois (24-48")
Rarden (<12")	Cincinnati (24-40")	Crosby (<18")	Otwell (24-36")
Zanesville (24-36")	Clermont (35-48")	Fincastle (24-48")	
	Hickory (<20")	Miami (<18")	
	Rossmoyne (24-40")	Russell (24-30")	
		Xenia (22-27")	

Sand Dunes

The primary concentration of sand dunes in Bartholomew County is a strip on the eastern edge of the flood plains and terraces of the Flatrock River and East Fork White River. This strip of dunes spans the entire north-south length of the county, reaches a maximum width of two miles, and is cut by several tributaries. Scattered dunes can also be found on the west side of the rivers. Active dune development is minimal at present.

The dunes formed over Wisconsinan ground moraine and outwash terraces. Where underlain by Wisconsinan ground moraine, the dunes cap the first upland ridge next to river. The stratigraphic contact between the two is sharp. Where the dunes overlie the outwash terrace, the elevation above the flood plain is much less and the contact between dune and terrace is expected to be gradational.

Dune thickness decreases further away from the rivers. One source estimated the average thickness to be 15 to 20 feet and in some places as much as 40 feet [9]. Many of the areas mapped have only 5 to 10 feet though, especially at locations furthest east of the river. In these areas, phantom drainage patterns in the underlying Wisconsinan ground moraine show through in the interdunal troughs. Some of the ridges in the Wisconsinan ground moraine close to areas mapped as sand dune are capped with fine wind blown sand (less than 5 feet thick).

The parent material of soils formed on sand dunes are predominantly fine uniform windblown sands. The surface soil is a sandy loam (A-4) to a depth of about 22 inches. Sandy clay loam (A-6 to A-4) is found from 22 to 47 inches followed by a thin layer of sandy loam (A-4) which becomes fine sand (A-2) at about 55 inches. The three agricultural soil series mapped in sand dune areas are Princeton, Ayrshire, and Bloomfield.

Glacial Landforms

Glacial deposits in Bartholomew County include Wisconsinan ground moraine, Illinoian ground moraine, and thin Illinoian ground moraine over sandstone-shale bedrock.

Ground Moraine of Wisconsinan Age

Wisconsinan ground moraine in Bartholomew County is characterized by a gently undulating land surface wherein the relief generally did not exceed 10 to 15 feet except in a few of the deepest valleys. Aerial photographs showed a mottled, light-dark pattern. The loess thickness ranges from 0 to 4 feet but is typically less than two feet [2]. Wisconsinan ground moraine occupies more than one-quarter of the surface area of the county.

Surface soil of the Wisconsinan ground moraine is a silt loam (A-6 or A-4) to a depth of 7 to 14 inches. Subsurface soils are silty clay loam (A-6) and clay loam as deep as four feet which is underlain by loamy soils with varying percentages of clay. The agricultural soil series formed in Wisconsinan ground

moraine in Bartholomew County are: Brookston, Crosby, Miami, Celina, Hennepin, Fincastle, Russell, and Xenia. Engineering test data from the Brookston series taken at one location in nearby Shelby County is given in Table 5. Generalized profiles developed from agricultural and borehole data are shown on the left-hand side of the engineering soils map which accompanies this report for the Wisconsinan ground moraine as well as all the other landform-parent materials.

Table 5. Engineering Test Data from the Wisconsinan Ground Moraine (NE, NW, Sec. 7, T.12N., R.7E., Shelby County) [14].

Brookston silty clay loam

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
0-7	1	26	51	22	43	19	A-7-6(11)	CL	15	108
20-34	-	20	53	27	40	21	A-6(12)	CL	16	112
38-48	8	47	53	27	40	7	A-4(4)	ML-CL	18	109

The combined thickness of the Wisconsinan ground moraine and underlying Illinoian ground moraine varies from 0 to 100 feet or more. Several boreholes show nearly 100 feet of glacial drift but are not common to any particular location. In most places, the bedrock is at 15 to 40 feet. Near areas mapped as limestone bench the depth varies from 0 to 50 feet. The Wisconsinan ground moraine is usually thicker than the Illinoian ground moraine where the former overlies the latter. Boreholes 28 to 32 were made in Wisconsinan ground moraine (see Appendix A and map).

Ground Moraine of Illinoian Age

Illinoian ground moraine in Bartholomew County is flat to moderately undulating and is cut sharply by gullies. Most of the western half of the county and a few square miles east of the East Fork White River in the southeastern part of the county have Illinoian ground moraine at the surface. Wisconsinan ground moraine overlies Illinoian ground moraine in much of the eastern half of the county. The thickness ranges from 0-100 feet.

Illinoian ground moraine is weathered as deep as 12 to 15 feet. The broad, flat areas are weathered deeper than the rolling, eroded areas. Most places have a cover of 2 to 4 feet of weathered loess. Engineering test data taken from one broad, flat area is shown in Table 6a. Unweathered ground moraine (loam) appears at a depth of 143 inches and contains more sand and less silt. Engineering test data from a rolling, dissected area in nearby Jennings County is given in Table 6b. At this location the silt content decreases with depth and the unweathered material is a clay loam. One characteristic common to most locations is the occurrence of a clay rich B soil horizon. Other borehole data is given in Appendix A (boreholes 35-38,41,43-46).

Table 6a. Engineering Test Data from a broad, flat area of Illinoian Ground Moraine (NW, SW, sec.14, T.8N., R.5E., Bartholomew County) [2].

Clermont silt loam

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
0-7	1	17	77	5	25	1	A-4(10)	ML	15	108
7-16	4	13	69	14	25	4	A-4(2)	ML	15	113
16-24	-	7	63	30	34	14	A-6(16)	CL	16	107
24-35	-	12	64	24	39	17	A-6(14)	CL	18	106
35-70	1	14	63	22	31	12	A-6(9)	CL	15	111
70-110	2	15	64	19	27	13	A-6(8)	CL	16	112
110-143	2	29	56	13	32	15	A-6(8)	CL	17	111
143-200	9	39	44	8	19	4	A-6(0)	ML	17	124

Table 6b. Engineering Test Data from a dissected area of Illinoian Ground Moraine (NW1/4, NW1/4, sec.10, T.6N., R.8E., Jennings County) [13]

Rossmoyne silt loam

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
3-9	2	13	58	27	30	7	A-4(8)	ML	15	108
27-43	10	16	44	30	26	9	A-4(8)	CL	16	112
85-129	5	28	30	37	32	13	A-4(8)	CL	18	109

The strength of the Illinoian ground moraine varies with depth. The initial 2 to 4 feet (weathered loess, A-4) is typically soft to medium stiff. The upper few feet of the weathered Illinoian ground moraine (A-6) is medium stiff which grades into the medium stiff to hard loamy unweathered material (A-6). Both the weathered and unweathered ground moraine are expected to be overconsolidated. Agricultural soil series which form on Illinoian ground moraine are: Avonburg, Clermont, Hickory, Rossmoyne, and Cincinnati.

Thin Ground Moraine of Illinoian Age

Illinoian ground moraine occurs near the Norman Upland and extends up the valleys a short distance. It is thin next to this unglaciated area as gully patterns characteristic of the sandstone-shale bedrock are visible in places. It was not possible to accurately locate all the thin areas but their occurrence is more frequent closer to the escarpment of the sandstone-shale plateau.

The texture of the thin Illinoian ground moraine is typically a silt loam (A-4) in the upper 10 to 18 inches. A clay, clay loam, or loam (A-6) will then extend down to bedrock with the last 6 to 30 inches containing partially weathered rock fragments from the underlying bedrock. The depth to bedrock is roughly five to ten feet.

Bedrock Landforms

Limestone Benches

Soils which form on limestone benches are primarily on the east side of the county. The soil is not as developed as it is for the shales on the west side of the county. It occurs as a surface soil along the steep slopes of some valleys. It is usually covered by thin Wisconsinan ground moraine or a veneer of slopewash. A few areas mapped as limestone bedrock occur as benches along streams but are subject to frequent erosion and may be capped with alluvial materials rather than residual soil. The bedrock benches are usually limestone but some shale beds occur in places.

Soils along the limestone valley slopes have about 10 to 13 inches of silt loam (A-4) at the surface. The next 7 to 25 inches is typically a clay loam (A-7). The residual soil next to the bedrock is 2 to 10 inches thick and is a silty clay (A-7). The contact between rock and soil is usually abrupt with little or no rock fragments in the profile. Solution susceptible limestones are rare in the county but are expected to have a much more developed soil profile. Agricultural soil series which form on limestone bedrock are: Milton and Corydon.

Sandstone and Shale Plateau

The sandstone and shale plateau is the escarpment area in the western part of the county associated with the Norman Upland. Soils formed from the weathering of the sandstone-shale bedrock are more developed on the flat uplands than the steeper side slopes of the eroded valleys. The slopes will have 4 to 10 inches of silt loam (A-4) underlain by 2 to 14 inches of silty clay loam (A-6). The next 6 to 14 inches is is a silt loam or silty clay (A-7) containing sandstone, siltstone, and shale fragments with bedrock below. A thicker layer of clay and shale fragments is expected to be found where the bedrock is the highly degradable New Providence Shale vs. the Locust Point Formation which contains resistant siltstone and sandstone layers along with degradable shale. The New Providence shale underlies the Locust Point Formation and occurs at the base of the Norman Upland as shown in Figure 6.

Soils formed on flatter surfaces (0 to 5 degrees) which have been subjected to less erosion and more intense infiltration tend to have a deeper profile. The upper 12 to 26 inches is a silt loam (A-4 or A-6). The next 15 inches is a silty clay loam (A-6 or A-4) followed by 16 to 20 inches of silt loam (A-6 or A-4), the lower half having scattered rock fragments. The weathered rock fragments increase in frequency in a loam matrix (A-6 or A-4) over the next 12 inches with bedrock defined below this layer. The total depth to bedrock is about four to six feet with the first one to three feet being weathered loess. The agricultural

soil series formed on sandstone and shale residual soils are: Berks, Gilpin, Rockcastle, Rarden, and Zanesville. Engineering test data for the Rarden series taken at one location in Bartholomew County is given in Table 7.

Table 7. Engineering Test Data from thin Loess over New Providence Shale Residual Soil (S5E, NW, Sec 34, T.8N. R.4E, Bartholomew, County) [2].

Rarden silt loam

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
0-3	-	2	88	10	30	1	A-4(1)	ML	20	95
3-8	4	4	68	24	30	5	A-4(5)	ML	19	106
8-18	3	10	58	29	39	13	A-64(8)	ML	17	104
18-26	3	6	57	34	4	16	A-7-5(17)	ML	20	104
26-38	-	12	64	24	39	13	A-6(14)	ML	17	110

Fluvial Landforms

Outwash Terraces

Broad coarse-grained outwash terraces occur along the edges of the flood plains of the three major rivers and larger tributaries. The terraces stand 5 to 20 feet above the flood plain and possess a distinctive current scar pattern on the aerial photographs. The terraces are extremely flat over several square miles and contain virtually no surface drainage due to their high permeability.

Boreholes 1 to 12, 16, and 34 were taken from terrace deposits. The upper 12 to 17 inches is typically a loam (A-4 or A-6) underlain by about 22 inches of gravely clay loam (A-2) or clay

loam (A-4). A silty clay loam may be present for another 16 inches but usually sand and gravel (A-1) is encountered which extends very deep (over 100 feet in places). Clay and silt layers are rare after the first five feet. Standard penetration tests in boreholes indicate the sand and gravel is very often medium dense to dense (see Appendix). In a few places slight, depressional channels in the terrace contain finer grained materials but only for the first few feet. Part of the terrace landform may be situated over a previous alluvial channel especially if it is close to the flood plain. Similarly it may overlie ground moraine near the outer edges. The primary agricultural soil series formed on terraces are: Ninevah, Fox, Martinsville, and Ockley. Engineering test data for the Nineveh, Fox, and Ockley series taken at specific locations is given in Table 8.

Table 8a. Engineering Test Data from an Outwash Terrace (SE, SW Sec 29, T.5N., R.7E., Shelby County) [14].

Nineveh loam

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
3-5	12	39	58	7	35	13	A-6(4)	SM-SC	14	116
13-25	26	43	44	22	51	31	A-2-7(3)	SC	14	112
35-45	54	41	30	3	NA	NA	A-1-a(0)	SW-SM	10	126

Table 8b. Engineering Test Data from an Outwash Terrace (SW, SW, Sec.35, T.5N., R.5E., Shelby County) [14].

Ockley loam

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
0-7	1	39	47	13	26	9	A-4(5)	SM-SC	14	116
27-35	18	37	15	30	60	42	A-7-6(9)	SC	14	112
46-60	56	36	4	4	NA	NA	A-1-a(0)	SW-SM	10	126

At another location (SW, NE, sec 14, T.13N., R.5E., Shelby County)

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
0-8	6	40	52	2	32	9	A-4(4)	ML-CL	16	109
16-29	23	39	16	22	47	27	A-7-6(5)	SC	16	110
46-56	17	68	7	8	NA	NA	A-1-b(0)	SM	12	117

Table 8c. Engineering Test Data from an Outwash Terrace (NE, sec 1, T.9N., R.5E., Bartholomew County) [2].

Fox loam

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
0-7	3	47	46	4	24	5	A-4(0)	ML	15	112
7-13	6	52	29	13	29	10	A-2-6-(1)	CL	13	116
13-26	13	55	14	18	34	12	A-4(8)	CL	18	110
26-33	11	71	11	7	NA	NA	A-3	SM	12	119
35-60	34	62	4	--	NA	NA	A-3	SW	10	112

Flood Plains

Soil deposits in the flood plains are very difficult to characterize due to their potential for variability within relatively short distances and depths. Nevertheless, there are some characteristic differences between the flood plain deposits due to their varying source areas. There are four distinctive types of flood plains in the county: the major river flood plains, those in Illinoian ground moraine, those in Wisconsinan ground moraine, and those in the sandstone and shale.

(a) Flood Plains of Major Rivers

The major rivers in Bartholomew County include the Flatrock River and the Driftwood River which join near Columbus to form the East Fork White River. The flood plains of these rivers are up to two miles wide and are commonly one mile wide. Topographically they are very flat with scattered small arc shaped depressions. These depressions typically contain finer-grained materials. Organic deposits occur occasionally on the surface and less frequently in the subsoil.

Many different agricultural soil series are recognized in major flood plains. The most common of these are Ross, Medway, Genesee, Saranac, Stonelick, Shoals, and Landes. The soil profile is made up of a variety of well to poorly graded, stratified soils. In some places sand and gravel becomes more dominant with depth since much of the valley was filled with coarse-grained outwash materials. Numerous gravel pits in the major flood

plains also testify to the abundance of sand and gravel below the more recent finer-grained deposits. Boreholes 5, 10 to 14, and 18 to 27 were made in the major flood plains.

(b) Flood Plains of the Illinoian Ground Moraine

Flood plains in the Illinoian ground moraine are typically less than one-half mile wide except near the southern border where the White Creek is over a mile wide. Most of the soils deposited in these flood plains were derived from the erosion of the Illinoian ground moraine and loess veneer. Lacustrine deposits may also be present below the recently deposited materials.

The surface soil is usually a silt loam (A-4) to a depth of 60 inches or more. Alternating layers of silt loam, silty clay loam, clay loam, and loam associated with the lacustrine deposits may continue at depth. Illinoian ground moraine or shale bedrock may also occur at a shallow depth in the flood plain. Boreholes 42 to 46 were made in the Illinoian ground moraine flood plain and show the silt loam surface soil to be soft to very soft. The agricultural soil series formed on flood plains near Illinoian ground moraine are Bonnie and Stendal.

(c) Flood Plains of the Wisconsinan Ground Moraine

Soils of the Wisconsinan ground moraine flood plains are similar to the major flood palin soils. Soils deposited there were derived from the erosion of thin loess and Wisconsinan ground moraine and also outwash materials.

The first 0 to 17 inches is typically a silt loam (A-4 or A-6) with the next 26 to 40 inches being a loam (A-4). The soil becomes more variable at depth with stratified silty loam, loam, sandy loam, and fine sand. Alluvial soils in those tributaries furthest to the western part of the Wisconsinan Ground Moraine region on the engineering soils map are more likely to be underlain by coarse-grained outwash deposits. Those near the eastern part of the ground moraine commonly have limestone bedrock near the surface. The most common agricultural soil series are Shoals, Genesee, and Eel.

(d) Flood Plains in Sandstone and Shale Plateau

Flood plains in the sandstone and shale plateaus are narrow and in many places could not be mapped due to scale limitations. The soils deposited there were derived from the erosion of the thin loess veneer and sandstone and shale bedrock.

The surface soil consists of a loam (A-4 or A-6) with rock fragments to a depth of 10 to 18 inches or a silt loam (A-4). Rock fragments continue to increase in frequency with depth with bedrock occurring at 30 to 108 inches. In some flood plains the profile is mainly silt loam with bedrock appearing deeper than 108 inches. It is also possible for a thin deposit of lacustrine material to be present in the wider flood plains. The agricultural soil series for sandstone and shale flood plains are Burnside and Haymond.

Lacustral Landforms

Lacustral Terraces

Lacustral terraces are the flat areas which are typically elevated less than 10 feet above the flood plains of the Illinoian ground moraine. They represent the surficial expression of the lacustral deposit which may extend below the terrace and the flood plain. They form a semi-continuous rim around the flood plain and do not extend more than one half mile away from the flood plain. The lacustral terraces are blanketed with a veneer of weathered loess up to four feet thick.

The soil profile consists of a silt loam (A-4) to a depth of 11 to 50 inches. Silty clay loam extends below to a depth of 66 to 80 inches followed by stratified silty clay loam, silty clay, and a few silt and fine sand layers to a depth of 108 inches or more. The depth of the lacustral material varies according to how close it is to the mouth of the tributary. Similar deposits in other counties are over 60 feet thick where the tributary meets a major river and are progressively thinner in the upstream direction [40].

Borehole 40 was made on a lacustral terrace and shows over 17 feet of lacustral material below about five feet of recent alluvium. The agricultural soil series for lacustral terraces are Dubois, Otwell, Bartle, and Peoga. Engineering test data for the Otwell series is given in Table 9.

Table 9. Engineering Test Data from a Lacustral Terrace (SW, NW, Sec. 11, T.7N., R.4E, Bartholomew County) [2].

Otwell silt loam

depth inches	Grav %	Sand %	Silt %	Clay %	LL %	PI %	AASHO	UNIFIED	Wopt %	Max γd pcf
0-5	1	12	77	9	27	1	A-4(1)	ML	18	105
5-8	-	10	69	13	25	2	A-4(1)	ML	16	108
8-19	-	6	63	19	33	8	A-4(8)	ML	18	106
19-30	-	9	64	23	34	11	A-4(10)	ML	18	107
30-42	-	11	63	19	28	9	A-6(8)	CL	15	113
42-58	-	10	64	28	30	11	A-6(8)	CL	16	109
58-79	2	35	56	15	21	5	A-4(1)	ML	14	116
79-112	-	31	44	12	30	11	A-6(6)	CL	16	113

Miscellaneous Landforms

Gravel Pits and Quarries

Gravel pits in Bartholomew County are very common in the major flood plains and alluvial outwash terraces. Some are as deep as 60 feet. A few gravel pits are found in the flood plains of the Wisconsinan and Illinoian ground moraine. One limestone quarry is in operation in the eastern part of the county located between Elizabethtown and Burnsville in sections 5 and 6 T.8N, R.7E. Sandstone beds of the Locust Point Formation in some areas of western Bartholomew County are sufficiently massive and resistant to have been quarried for building stone in the past [10].

ENGINEERING PROBLEMS OF BARTHOLOMEW COUNTY

Introduction

The following section is devoted to the engineering problems associated with the soils and rocks of Bartholomew County. Potential problem soils and rocks are specifically discussed for various types of engineering works. It is included to provide a more accurate picture of the field conditions so that better decisions can be made in the design and construction stages.

This section is divided into six main sections:

Dams
Shale and Fill Embankments
Steel and Concrete Corrosion
Slope Stability
Foundations and Excavations
Waste Disposal

Dams

Topographically, the most favorable locations for dams in Bartholomew County are (1) the deep alluvial valleys on the eastern side of the county where the Wisconsinan ground moraine is thin or completely eroded over limestone bedrock and (2) in the western part of the county where the rolling hills of the Illinoian ground moraine merge into the steep sandstone and shale uplands. There are no known areas where a dam cannot be built in

the county if the problems associated with the rocks and soils in the proposed area are anticipated. Several important design elements should be considered. These are:

1. Compacted Materials
2. Compressibility and Strength of Foundation
3. Leakage Potential
4. Embankment Slope Stability

Compacted Materials

The Illinoian and Wisconsinan ground moraine have similar compactive properties. They have fair to good workability [2] and good shear strength. The unweathered portion of the till (greater than 3-5 feet for Wisconsinan ground moraine; greater than 5-10 feet for Illinoian ground moraine) has good resistance to piping. It makes an excellent embankment material. The weathered portion is typically silty and in addition may have up to four feet of weathered loess [2] which makes it susceptible to erosion. This weathered material should be protected from erosion or only be used in the embankment interior. Beds of gravel and sand encountered in the ground moraine can be used in the embankment unless the gravel and sand constitute a large portion of the deposit [9].

Lacustrine soils possess poor to fair shear strength when compacted. Close control of the moisture content is necessary during compaction [15]. The lacustrine terraces are silt dom-

inant and are, therefore, susceptible to erosion and should be covered with erosion resistant material if used as a downstream berm.

Alluvial soils are quite variable and can be classified as suitable for embankment fill only on a site specific basis. Some areas mapped as flood plains in the Illinoian ground moraine and sandstone and shale uplands may contain lacustrine soils. Organic materials are occasionally encountered which should be avoided. Alluvial soils can be used with success but care must be taken to sort out any undesirable material.

The sandstone and shale residual soils can be coarse-grained depending on which parent material is predominant. Piping potential is high for the silty/sandy soils and low for the clayey soils. Mixing the different soil types usually produces a higher shear strength, better workability, and lower piping potential but both soils are susceptible to erosion and should be covered with erosion resistant material [16].

Table 10 rates the various compacted properties according to soil type.

Compressibility and Strength of Foundation Materials

It is very possible for a dam in the western part of the county to be situated on alluvial valleys filled with lacustrine soils. These deposits are thickest where the tributaries meet the East Fork White River (20 to 60 feet [17]) and thin going up

Table 10. Factors Affecting Dam and Pond Performance.

Soil Type	1 Piping Resistance	2 Compacted Shear Strength	3 Uncompacted Shear Strength	4 Compacted Permeability	5 In-situ Permeability
Wisconsinan till	good	good	fair	low	low
Illinoian till	fair-good	good	fair	low	low
Lacustral soils	fair	poor	poor	low	very low
Outwash terraces	fair	good	good	high	high
Floodplains in					
Wisconsinan till	fair	fair-good	fair-good	mod-low	low-high
Illinoian till	poor	fair	poor	mod-low	low-mod
Sandstone-Shale	fair-poor	fair	fair-poor	moderate	moderate
Sandstone-Shale residual soil	poor-good	fair	fair-poor	low-mod	low-mod
Sandstone-Shale	n.a.	good*	good	low-mod**	low

* Shale will degrade with time and considerable strength will be lost (See section on shale fill and embankments).

** Permeability decreases with time as shale degrades and voids collapse.

These table ratings represent the average character of the soil groups. Actual conditions may vary considerably within a soil deposit and/or at a particular site.

westward toward the sandstone and shale escarpment. These materials are most likely normally consolidated and are soft [12]. A large embankment placed on a lacustrine deposit may experience intolerable settlements which can cause cracking. If a significant thickness of this material is discovered during exploration, undisturbed sampling and consolidation testing is in order. Monroe Dam in Monroe County was built on 60 feet of similar lacustrine material. The embankment load was placed in stages allowing the silt and clay to consolidate under controlled conditions [12]. The load was spread over a wider area to reduce contact pressure. In some cases, it is easier to excavate the material if it is weak and thin. Similar practices are used to accommodate the low bearing capacity of this material.

Alluvial materials in the eastern part of the county are good or poor and must be considered on a site specific basis. In areas mapped as bedrock alluvial cover is shallow or absent. In those areas where bedrock is not shallow, ground moraine or outwash may underlie the stream. Boreholes 33 and 34 were made in flood plains of the Wisconsinan ground moraine and show outwash and ground moraine beneath the alluvial soils.

Ground moraine (till) serves as an excellent foundation material. Both the Illinoian and Wisconsinan ground moraine are expected to have been subjected to strong preconsolidation pressures at the time of deposition. The principal drawback with till is the extreme textural variability within short distances which tend to promote differential movements.

The bedrock in the eastern part of the county is for the most part a sound foundation material. Thin layers of weak shale interbedded within the limestone do occur but can be dealt with once identified [9]. Solution cavities which may also pose a threat to abutments are the exception in the limestone and dolomite. The North Vernon Limestone and upper part of the Jeffersonville Limestone are relatively pure calcium carbonate and commonly have solution cavities [9]. These limestone units along with weak Silurian shales outcrop in some of the eroded eastern stream valleys and continue into Jennings and Decatur Counties [9]. These units dip to the southwest at a slight angle (less than two percent) and therefore lie in a roughly north-south strip most of which is covered by Wisconsinan ground moraine (0-100 feet). It is likely that the ground moraine has filled in the cavities since the aerial photographs used in this study did not reveal any distinct solution features. Changing the groundwater regime in these areas may accelerate the solution process though.

Bedrock in the western part of the county has proven to be an adequate foundation material. The poor durability of the shales there should be considered though, especially under important structures such as a concrete spillway. In the construction of the spillway for Grandview Dam, the weathered portion of the underlying New Providence Shale was excavated away [18]. It is not clear what type of protection from further weathering was taken but protection is advisable for this material.

Leakage Potential

Lacustrine soils allow very little seepage under a dam. This fact may make it advantageous to leave this soil in place if the strength and compressibility concerns are not overwhelming. Within or below the lacustrine soils may lie thin layers or channels of coarser materials deposited before and in between lacustrine deposition [12]. These coarse-grained layers should not pose a problem though.

Alluvial soils are much more variable and need to be explored adequately. The alluvial soils in the Wisconsinan ground moraine tend to contain more sand and gravel deposits than the alluvial soils in the Illinoian ground moraine due to their source areas. The sandstone and shale alluvial valleys can contain more coarse grained materials but are mainly silty and will allow some seepage. Sand and gravel will be common in the major alluvial valleys, but in these broad, flat areas seepage may not be so critical if the dams are intended only for temporary retention of floodwaters. An excellent complement to borehole exploration is an electrical resistivity survey. This method can cover a wide area cheaply and locates sand and gravel outwash deposits (high resistivity) easily.

Another possible leakage path is through a valley wall via joints or gravel seams to an adjacent watershed. This may be a problem in the eastern part of the county if a limestone solution tunnel or a joint is large and continuous to an adjacent valley.

Leakage in this manner through the Wisconsinan or Illinoian ground moraine is unlikely due to the long permeable channel necessary in the texturally variable till. The path needed for leakage is much less in the steeper sandstone and shale plateau. Permeable sandstone beds with joints and residual soil may provide a leakage path there. Although possible, this mechanism of leakage is not likely to be as important as other means.

The third general leakage path is seepage around the abutments of a dam. Sandstone and shale colluvial slopes contain large rock fragments which allow large voids to exist. If exploration reveals this to be the case, excavation or sealing with a impermeable liner may be necessary. Joints in the bedrock may also allow seepage around an abutment. Joints in the Locust Point Formation are widely spaced (3-10′ [16]) and "tight" and, therefore, usually do not cause problems. An exception to this case was the dam on Cordry Lake (166 acres) just 1.5 miles across the border into Brown County. Excessive leakage prompted an attempt to grout the underlying bedrock but this measure helped very little. One explanation is that the leakage was occurring through stress relief joints parallel to the valley walls rather than the underlying bedrock [36]. Leakage in the solution prone limestones is possible if the abutments are left unprotected.

Embankment Slope Stability

Proper proportioning of the sideslopes and top width of a dam are important to insuring its stability. Uplift and lateral pressures exerted by the impounded water along with the weight of the embankment soil must be counterbalanced by adequate shear strength of the embankment soil. Some simple safe sideslope proportion recommendations for embankments less than 25 feet are given in Table 11a for the upstream and downstream slopes. Table 11b gives recommended top widths corresponding to different dam heights.

Shale Fill and Embankments

State roads and larger county roads constructed in the rugged sandstone and shale plateau area of the county have required cut and fill construction methods. Problems arise when over time the shale weathers into a soil-like material. Voids in the once mechanically strong material subsequently collapse giving rise to intolerable settlements and embankment slope instability.

In order to predict and optimize the performance of these shales as a fill material a system has been devised. The system consists of several tests which allow the shale to be rated. Charts which correlate this rating with construction practice and soil parameters are then used to design and build.

Table 11a. Recommended Side Slopes for Earth Embankments (33).

Fill Material		Side Slopes Horizontal to Vertical	
		Upstream	Downstream
Clay CH			
Clayey sand SC	Sandy clay CL	3 to 1	2 to 1
Silty clay CL	Silty sand SM	or	
Clayey gravel GC	Silty gravel GM	2½ to 1	2½ to 1
Silt ML or MH	Clayey silt ML	3 to 1	3 to 1

Table 11b. Recommended Top Widths for Earth Embankments (33).

Height of Dam (feet)	Top Width (feet)
Under 10	8
10 to 15	10
15 to 20	12
20 to 25	14

The slake durability test simulates long term degradation due to weathering. Five, ten-gram shale pieces are placed in a rotating drum half submerged in a water bath. After 200 revolutions the shale is taken out, oven dried, and then put through another 200 revolution cycle. The shale left in the drum is then weighed and its slake durability index is computed as follows:

$$Id(2) = \frac{\text{Weight after 2nd cycle}}{\text{Weight before 1st cycle}} \times 100$$

Soils with Id(2) less than 80 are classified as soil-like and are expected to act like soil if allowed to weather. The shales in the hilly part of Bartholomew County (New Providence and Locust Point Formations) are classified as soil-like. The New Albany shale which underlies the middle portion of the county is expected to be slightly more resistant to degradation but mechanically weak.

Combining the slake durability test with the plasticity index (if Id(2) greater than 80 would use point load test instead of plasticity index) the shale can be rated by the Franklin rating chart (Figure 10). The plasticity indices of the New Providence and Locust Point Formations found in other parts of the state range from 8 to 12 percent [32].

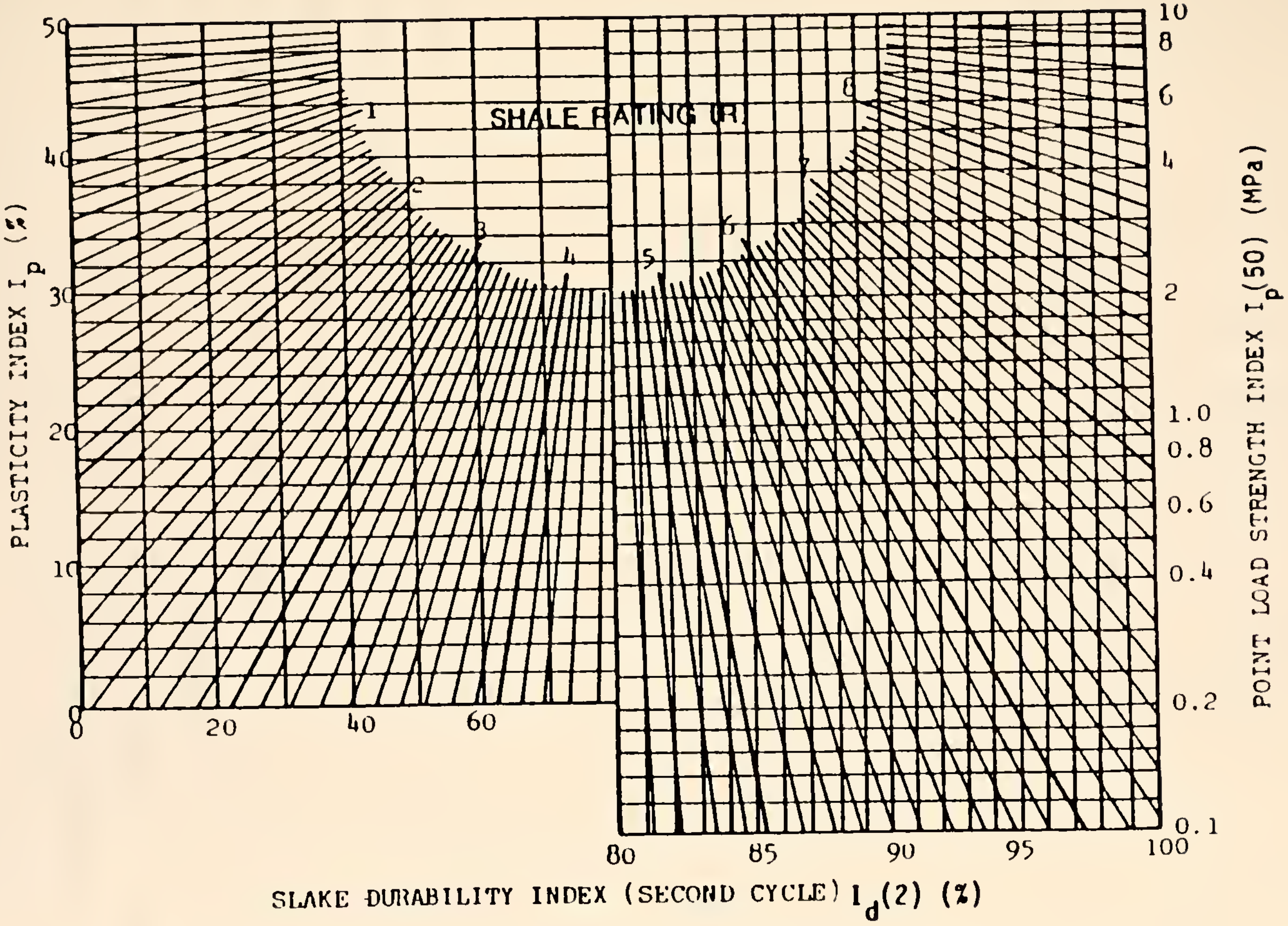


Figure 10. Shale Rating Chart, after Franklin (34).

Compaction degradation tests on these shales indicate that they are difficult to break down even though they behave as soil-like material in the long term. This poor combination necessitates the use of strict compaction control during construction. Figure 11 shows trends in the shear strength parameters of compacted shale fills as a function of the `R´ rating. Figure 12 gives minimum lift thicknesses and compacted field densities as a function of `R´.

Within the Locust Point Formation are sandstone and siltstone layers of which fragments may not break down even under reduced lift thickness. If this is a problem or even if it is economically desirable to place the shale as rock fill some precautions can be taken. One way is to isolate the shale from water. Encasing clay layers near the surface of the embankment and placing good vegetative cover helps to control infiltration [19]. Providing good drainage helps to minimize slaking too. Vertical and horizontal drains can be very effective. A freely draining rock pad under the fill is effective in carrying away water which infiltrates down through the embankment or along the cut fill interface [19]. It is impossible to prevent slaking from occurring but if proper measures are taken during construction the life of the embankment can be considerably prolonged.

Steel and Concrete Corrosion

Approximately half of the soils in Bartholomew County are susceptible to steel and concrete corrosion. These soils include

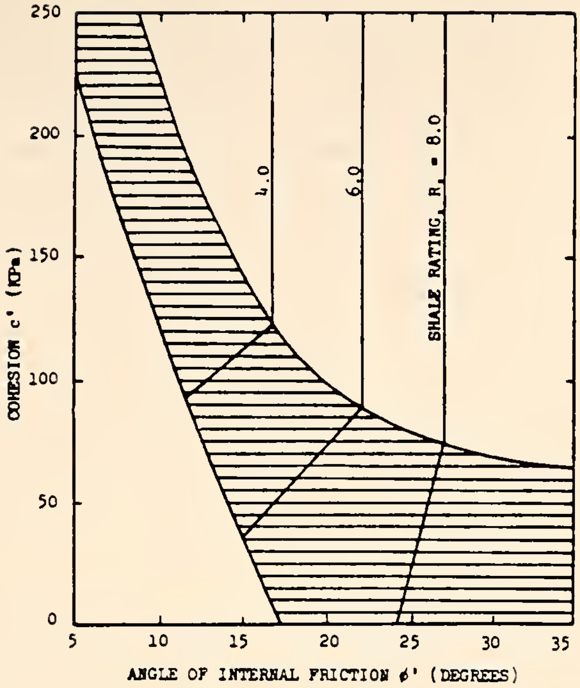


Figure 11. Trends in Shear Strength Parameters of Compacted Shale Fills as a Function of the Shale Quality (34).

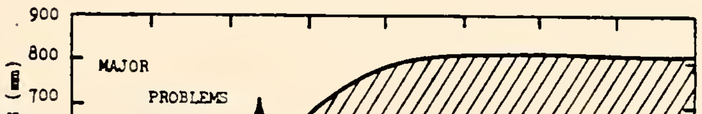


Figure 12. Tentative Correlations Between Shale Quality, Lift Thickness and Compacted Densities (34).

the Illinoian ground moraine, sandstone and shale residual soil, lacustrine soil, and the alluvial plains within these areas. The pH of these soils is typically around 4.5 to 5.5 for the first five feet and reaches 7.0 to 8.4 within a depth of 10 feet [2]. These acidic soils reduce the useful life span of buried steel piping to 15 years or less [16]. It is common practice now to use aluminum pipes instead of steel [37]. Aluminum is more resistant to corrosion as well as being lighter, cheaper, and easier to place [37].

The performance of concrete is dependent on the quality of the concrete. In similar conditions in neighboring Brown County, poor quality concrete on private bridges was severely pitted and eroded jeopardizing structural integrity. Good quality concrete suffered only minor surface pitting [16].

Slope Stability

There are no known natural slope failures in Bartholomew County. The potential for slope instability arises when slopes are altered in one or more unfavorable ways. These ways include: (a) oversteepening by a cut, (b) removal of toe support, (c) saturation of the slope, (d) overloading the head of the slope.

The lacustrine terraces are susceptible to slope failure. These terraces are generally 5 to 15 feet above the flood plain and, therefore, offer good flood protection to structures built there. Building a moderately heavy structure on the edge of the terrace may lead to instability. Natural slopes are not a

reliable guide to acceptable cut angles. This is because natural slopes have drained shear strength parameters (c' and ϕ') resisting sliding while cut slopes have undrained shear strength parameters ($\phi = 0$). The slow permeability of the lacustrine deposit does not allow dissipation of shear induced porewater pressures. Cut design therefore should be based on undrained shear strength analysis. Because of the low permeability of this lacustral soil, drains will not be an effective means of reducing shear induced porewater pressures.

The other soil type with moderate potential for slope instability is the sandstone and shale residual soils. These soils on the lower slopes are generally three to ten feet thick and are susceptible to sliding along the planar rock-soil interface. These same soils in Brown County have been reported to be unstable on slopes at 30 to 45 degrees [16]. Usually the slope is first weakened by removal of the toe for some purpose and then fails after rain saturates the soil. Based on a simple planar slope stability analysis, it was found for a slope of 45 degrees with unconfined compressive strengths ranging from 250-500 psf (a rough estimate) that the minimum critical soil depth ranged from 4-7 feet [16]. Slope movements should be anticipated on road cuts where the residual soil is over six feet thick and on a steep slope, especially during and after a heavy rainfall.

The road around Grandview Lake has suffered from movements of the underlying residual soil. A section of road 200 feet long sunk several inches severing a sewage line [38]. Movement of the

road was correlated to periods of rainfall. Expensive houses built on the steep slopes surrounding the lake have had similar problems. These homes were generally built on small shallow footings with no soil exploration [39].

Foundations and Excavations

Most of the heavy buildings in Bartholomew County are in the city of Columbus. Most of the city is founded on an outwash terrace from 10 to over 100 feet thick. Scattered borehole data in the area shows it to be mainly sand and gravel and occasionally containing a few thin clay layers (less than 5 feet) [6]. The first one to five feet tends to be clay rich but can easily be removed. Weak and compressible soils such as soft clay layers within glacial till or alluvial soils which underlie the outwash terrace are significant where the outwash terrace is thin. Most all mat and footing foundations have performed well in Columbus but proper soil exploration should be done for new buildings to ensure that clay pockets, soft materials at shallow depths, and loose sands pose no settlement or stability problems to foundations.

Excavations on the sand and gravel terrace may need strong dewatering measures due to the high permeability of the soil and high water table (3 to 10 feet [39]). Sideslopes are usually not braced and can be cut at the angle of repose since space is usually not a problem. Steel sheet piles were used though to protect the highway next to the 18 foot excavation of the Cummins

headquarters building while the other faces were left unbraced [39]. Borehole 4 (see map) was made under the same building.

Bridges are the primary foundation concern elsewhere in the county. Their foundations are either H piles driven to bedrock or steel shell friction piles [39]. A few problems have arisen due to slope caving in sandy excavations. Another potential problem for deep bridge excavations in the major alluvial valleys are blowouts. These can occur when water pressure from a sand and gravel deposit below is greater than the weight and friction of the soil in the bottom of the excavation. Soil borings should precede such excavations to locate sand and gravel layers with this potential to flood the excavation.

Waste Disposal

Suitable areas for waste disposal landfills in Bartholomew County are present. There are also many poor areas. The alluvial terraces are very permeable and are susceptible to rapid contamination. The flood plains, although containing sufficient impermeable areas, should be ruled out due to occasional flooding. The lacustrine terraces where high enough above the flood plain and possessing enough surface area are a possibility. The Wisconsinan and Illinoian ground moraine are probably the best areas. Their low permeabilities and available cover material offer the best guarantee against groundwater contamination. Detailed exploration of the ground moraine is necessary with particular attention paid to sand and gravel seams [20].

SUMMARY

Table 12 is a summary of the potential engineering problems of Bartholomew County related to the landform-parent material areas shown on the engineering soils map. Each soil type found in the county is rated for its likelihood of major problems occurring for a number of activities. The ratings reflect the average character of the soils and should be viewed with this in mind.

SYMBOL EXPLANATION

LIKELIHOOD OF A MAJOR PROBLEM DEVELOPING

L - LOW
M - MEDIUM
H - HIGH

PERMEABILITY

1 - LOW
2 - MEDIUM
3 - HIGH

		CUT DESIGN						EMBANKMENT FILLS					EMBANKMENT FOUNDATION			HIGHWAY SUBGRADE				FOUNDATION DESIGN					MISCELLANEOUS		
									COMPACTED PROPERTIES											SHALLOW FOOTINGS		PILES					
LAND FORM	GENERAL SOIL TEXTURE	SOIL BACKSLOPE STABILITY	ROCK BACKSLOPE STABILITY	GROUNDWATER CONTROL	EROSION	SURFACE DRAINAGE	NATURAL SLOPE AND RIVER BANK STABILITY	EROSION	RELATIVE PERMEABILITY	SHEAR STRENGTH	COMPRESSIBILITY WHEN SATURATED	WORKABILITY	SETTLEMENTS	SHEAR STRENGTH	ORGANIC DEPOSITS	SUBGRADE SUPPORT	FROST ACTION	PUMPING	SHRINK-SWELL	BEARING CAPACITY	SETTLEMENTS	BEARING CAPACITY	SETTLEMENTS	NEGATIVE SKIN FRICTION	SHALLOW RESIDENTIAL SEPTIC SYSTEMS	STEEL CORROSIVITY	CONCRETE CORROSIVITY
Wisconsinan Ground Moraine	Silt, Clay and Sand	L		L	L/M	M	L	M	1	L/M	M	L	L	L	L/M	L	M/H	M	M	L	L	L	L	L	M/H	L	L
Illinoian Ground Moraine	Silt, Clay and Sand	L		M	M	M	L	M	1	L/M	M/L	M/H	L/M	L/M	L	L	M/H	H	M	L	L	L	L	L	H	M	H
Thin Illinoian Ground Moraine	Silt, Clay and Sand	L		L	M	M	L	M	1	L/M	M/L	M/H	L/M	L/M	L	L	M/H	M	M	L	L	L	L	L	H	M	H
Sand Dunes	Sand, Silt and Clay	L		M	H	L	L	H	3	L	L	L	L	L	L	L	L/M	L	L	L	L	L	L	L	H	L	L
Outwash-Terraces	Sand, Silt and Gravel	L		M/H	M	L	L	M	3	L	L	L	L	L	L/M	L	L/M	L	L	L	L	L	L	L	L	L	L
Lacustral Terraces	Silt, Clay and Sand	H		L	M/L	H	M	L	1	H	H	H	H	H	M	M	H	M	M/H	H	H	M	M/H	H	H	M	H
Flood Plains of Major Rivers	Silt, Sand and Clay	M		M	H	L/M	M	M	1-3	M	M	M/L	H/L	H/M	M/H	M	M	M/L	L	M/H	M	L/M	L/M	M	H	L	M
Flood Plains of Ill. Grd. Moraine	Silt, Clay and Sand	M		L/M	M	M/L	L	M	1-2	M	M	M/L	H/L	H/M	M/H	M	M	M/L	L	M/H	M	M	M	M	H	M	H
Flood Plains in Wisc. Grd. Moraine	Silt, Clay and Sand	M		M	M/H	M/L	L/M	M	1-2	M	M	M/L	H/L	H/M	M/H	M	M	M/L	L	M/H	M	M	M	M	H	L	L
Flood Plains in Sandstone-Shale	Silt, Clay and Sand	M		M	M/H	L/M	L	M	1-2	M	M	M/L	H/L	H/M	M/H	M	M	M/L	L	M/H	M	M	M	M	H	M	H
Residual Soil on Sandstone-Shale	Clay and Sand	M/H		M	M	H	M	M	1-2	L/M	M/H	M	M	M	L	M/L	M	H	L/M	M	M	L	L	M	M/H	H	H
Sandstone-Shale	Rock		L	L/M	L	H	L	L	2	M	L	H	L	L	L	I	I	I	I	I	I	L	L	L		H	H
Limestone Bench	Rock		L	L	L	H	L	L	1	I	I	H/M	I	L	I	I	M	I	I	I	I	I	I	L		M	I

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37. David L. Hayward (P.E.), Bartholomew County Engineer

38. Ron May (P.E.), consulting engineer, former Bartholomew County Engineer.

39. George Dutro, Columbus City Engineer.

40. H.H. Gray, Geologist at the Indiana Geological Survey.

Borehole Number	Highway Route	Station	Offset	Surface Elevation	Depth	Soil Description		SPT*	LL	PL	PI	Notes
						Texture	AASHO					
		feet	feet		feet			blows/foot	%	%	%	
INTERSTATE 65 [22].												
1	1-65	3632 + 207	CL	661.2	0-3.5	loose SANDY LOAM						sand and gravel outwash terrace
					3.5-5.5	loose SAND & GRA		5				
					5.5-7.0	very loose FINE SAND		4				
					7.0-17.0	med. dense SAND & GRA		22,28				
					17.0-23.0	med. dense FINE SAND		21				
					23.0-37.0	med. dense SAND & GRA		19,15,16				
					37.0-50.0	med. dense SAND & GRA		30,16,23				
2	1-65	3745 + 47	CL	674.8	0-6.0	fine SANDY LOAM		6				dune
					6.0-8.0	med. stiff SANDY CLAY LOAM		7				sand and
					8.0-15.0	loose to dense SAND & GRA		4,12				gravel
					15.0-45.0	med. dense FINE SAND & GRA		13,10,14, 30,34,38				outwash terrace
					45.0-50.5	very stiff SANDY CLAY LOAM		27				ground
					50.5-51.5	very stiff SILTY CLAY LOAM		25				moraine
3	1-65	3605 + 55	62L	658.0	0-4.0	loose SANDY LOAM		4				sand and
					4.0-12.0	loose SAND & little gra		6,8				gravel
					12.0-33.0	loose SAND & GRA		35,13,28,30				outwash
					33.0-36.0	m.dense SAND & little gra		15				terrace
					36.0-50.0	dense SAND & some gra		51,30,28				
CUMMINS HEADQUARTERS BUILDING, COLUMBUS [23].												
4				626.9	0-3.0	SANDY SILTY CLAY & tra gra		11				sand and gravel outwash terrace
					3.0-6.0	med. dense CLAYEY SAND		11				
					6.0-17.0	loose SAND & trace gra		10,18,35				
					17.0-27.0	med. dense CLAYEY SAND & trace gra		11,17				
					27.0-32.0	med. dense SILTY SAND w/tra fra & clay		14				
					32.0-37.0	med. dense slightly cemented SAND		34				
					37.0-42.0	med. dense SILTY SAND & little gra		23				
					42.0-52.0	med. dense SAND & tra gra		40,65,56,32				
					52.0-72.5	dense SILTY SAND & tra gra		45				
					72.5-78.0	dense FINE SAND		13				
					78.0-82.6	med. dense FINE SAND						
					82.6-87.6	hard thinly laminated SHALE w/few thin limestone seams						New Albany shale
WATER EXPLORATION FOR COLUMBUS [24].												
5				612	0-3.5	med. stiff SILTY CLAY						
					3.5-8.5	stiff SANDY CLAY & tra gra		12				
					8.5-18.5	loose SAND & tra gra		6,10				

*STP = Standard Penetration Test, the number of blows from a 140 lb. hammer needed to drive the split spoon sampler 12 inches

APPENDIX A — Borehole data from Bartholomew County.

Borehole Number	Highway Route	Station	Offset	Surface Elevation	Depth	Soil Description		SPT*	LL	PL	PI	Notes
						Texture	AASHO					
		feet	feet		feet			blows/foot	%	%	%	
					18.5-68.5	med. dense to dense SAND & tra gra		20,11,32,49 24,34,45,66 66,47,43				terrace (outwash)
					68.5-85.0	very dense SAND & tra gra		34/9",98/10", 82				
					85.0	BEDROCK						
6				618	0-3.5	med. dense SANDY SILT						sand and gravel outwash terrace
					3.5-13.5	loose to med. SANDY SILT & tra gra		22,3				
					13.5-53.5	med. dense to dense SAND & tra gra		21,22,25,40 21,34,29,44				
					53.5-66.0	dense SILTY SAND & tra gra		48,51,41				
					66.0-73.5	dense FINE SAND & tra gra		40				
					73.5-78.5	very dense SILTY SAND & tra organic		68				
					78.5-93.5	dense FINE SAND		44,43,48				
					93.5	BEDROCK						
7				610	0-8.5	very soft CLAYEY SAND		4				sand and gravel outwash terrace
					8.5-13.5	med. dense SAND		28				
					13.5-62.5	med. dense SAND & tra gra		20,28,21,30, 32,75,58,37, 32,26				
					62.5-68.5	v. dense SAND & tra gra		54				
					68.5-73.5	dense FINE SAND & tra gra						
					73.5-91.0	dense SAND						
					91.0	BEDROCK						
8				620	0-3.5	stiff SANDY SILT						sand and gravel outwash terrace
					3.5-8.5	med. dense SILTY SAND & GRA		22,17				
					8.5-42.5	med. dense SAND & tra gra		29,26,19,20, 16,25				
					42.5-45.0	med. dense SILT		26				
					45.0-57.5	med. dense SILTY SAND & tra gra		17,28				
					57.5-68.5	dense SANDY SILT		32,45				
					68.5-72.5	med. dense SANDY SILT		18				
					72.5-78.5	med. dense SILTY SAND		19				
					78.5-83.5	med. dense SILTY SAND		50/4"				
					83.5-107.0	very dense SAND & tra gra		54,93/9" 59,57,56				
					107.0	black SHALE						New Albany Shale
9				618	0-3.0	med. dense SANDY SILT						sand and gravel outwash terrace
					3.0-8.5	loose SILTY SAND & tra gra		7				
					8.5-13.5	med. dense SAND & some gra & clay		16				
					13.5-33.5	med. dense FINE SILTY SAND		18,27,27,25				

APPENDIX A (cont.)

Borehole Number	Highway Route	Station	Offset	Surface Elevation	Depth	Soil Description		SPT*	LL	PL	PI	Notes
						Texture	AASHO					
		feet	feet		feet			blows/foot	%	%	%	
					33.5-48.5	dense SAND & tra gra		46,33,29				
					48.5-53.5	dense FINE SAND		44				
					53.5-68.5	med. dense SILT & tra clay		23,34,39				
					68.5-78.5	dense to v.dense FINE SAND		79,34				
					78.5-102.0	v.dense to dense SAND w tra gra		49,88,40,44, 36				
					102.0	BEDROCK						
10				615	0-8.5	med. stiff CLAYEY SILT		8				alluvium sand and gravel outwash terrace
					8.5-43.5	med. dense to dense SAND & tra gra		11,15,13,36, 27,28,42				
					43.5-65.0	med. dense to dense FINE SAND		29,29,58,18, 24				
					65.0-68.5	very stiff SILTY CLAY						
					68.5-70.0	black SHALE		65				
					70.0	black SHALE						
11				614	0-8.5	med. stiff SILTY CLAY		7				alluvium or outwash
					8.5-13.5	very loose SILTY SAND & tra clay		4				
					13.5-28.5	med. dense to loose SAND & tra gra		18,26,7,7				
					28.5-43.5	med. stiff to v. stiff SANDY SILTY CLAY w/ gra & sand layers		9,29				
					43.5-60.0	very stiff to stiff SILTY CLAY		26,12,11,15				glacial till or recent alluvium
					60.0-68.5	med. dense CLAYEY SILT		12				
					68.5-77.0	stiff to hard SILTY CLAY w/ seams of sand		16,35				
					77.0	BEDROCK						
12				620	0-3.5	med. dense SANDY SILT						fine-grained outwash or alluvium
					3.5-13.5	med. dense SAND & GRA		23,38				
					13.5-18.5	hard CLAYEY SANDY SILT & tra gra		38				
					18.5-23.5	med. dense SAND & GRA		16,18				
					23.5-38.5	very stiff SILTY CLAY w/ layers of sand		45,38				
					38.5-48.5	dense SILTY SAND		42,43				
					48.5-53.5	dense SAND & tra gra		45,42				
					53.5-68.5	very stiff SILTY CLAY w/ tra gra		30,36				glacial till
					68.5-70.0	dark brown SHALE		97/9"				
13				620	0-13.5	med. stiff CLAYEY SILT		9,11				alluvium
					13.5-18.5	med. stiff SILTY CLAY		8				
					18.5-23.5	med. dense SAND & GRA		23				

APPENDIX A (cont.)

Borehole Number	Highway Route	Station	Offset	Surface Elevation	Depth	Soil Description		SPT*	LL	PL	PI	Notes
						Texture	AASHO					
		feet	feet		feet			blows/foot	%	%	%	
					23.5-43.5	med. dense SAND & tra gra		15,7,16,20				
					43.5-48.5	very dense SANDY SILT		78				
					48.5-72.0	stiff to very stiff SILTY CLAY		12,22,17,16, 29				
					72.0-75.0	BEDROCK						
14				617	0-8.5	med. stiff SILTY CLAY & tra gra		7				alluvium
					8.5-13.5	very soft SANDY SILT		2				
					13.5-18.5	stiff SANDY CLAY		14				
					18.5-58.5	dense to med. dense SAND & tra gra		41,20,13,14, 26,43,32,30				
					58.5-61.5	hard SILTY CLAY		38				
					61.5	BEDROCK						
15				640	0-3.5	stiff SANDY CLAY						
					3.5-18.5	loose to very loose SILTY SAND		10,7				
					18.5-28.5	med. to v. stiff SANDY CLAY		7,18				
					28.5-33.5	med. dense SILT		16				
					33.5-42.0	med. stiff SILTY CLAY		14,18				
16				635	0-8.5	med. stiff CLAYEY SAND		9				sand and gravel outwash terrace
					8.5-43.5	med. dense to dense SAND & tra gra		26,45,26,19, 26,32,35				
					43.5-48.5	med. dense SAND & GRA		30				
					48.5-87.0	stiff to hard SILTY CLAY		34,17,13,9, 14,18,19,44				glacial till
					87.0	BEDROCK						
17				636	0-3.5	soft SANDY CLAY						alluvium
					3.5-8.5	very loose SAND		5				
					8.5-18.5	loose CLAYEY SILT		9				
					18.5-26.5	med. to very stiff SILTY CLAY						glacial till
					26.5	SHALE						
18				621	0-3.5	med. stiff SANDY CLAY						alluvium
					3.5-8.5	loose SILTY SAND		10				
					8.5-23.5	med. dense SAND & GRA		14,19,29				
					23.5-28.5	dense SAND		36				
					28.5-38.5	hard to v. stiff SANDY CLAY		34,22				
					38.5-42.5	med. stiff SILTY CLAY		12				
					42.5-60.0	loose to med. dense FINE SAND		7,11,10,9				
					60.0-78.5	very stiff SILTY CLAY		18,24,23				glacial till or old alluvium
					78.5-100.0	very stiff CLAY		29,22,23,18				
					100.0	LIMESTONE						

APPENDIX A (cont.)

Borehole Number	Highway Route	Station	Offset	Surface Elevation	Depth	Soil Description		SPT*	LL	PL	PI	Notes
						Texture	AASHO					
		feet	feet		feet			blows/foot	%	%	%	
						STATE ROAD 46 [25].						
19	SR 46	878+00	15L	620.2	0-2.4	loose GRA & SAND	A-1-6					alluvium
					2.4-5.3	loose SANDY LOAM	A-2-4(0)		23	15	8	
					5.3-6.0	loose GRAVELY SAND	A-1-6					
20	SR 46	890+00	20L	614.3	0-3.5	loose SANDY LOAM	A-2-4	7				alluvium
					3.5-8.0	med. stiff CLAY LOAM	A-6					
					8.0-10.0	loose GRA & SAND	A-1-6	10				
21	SR 46	900+00	2R	616.3	0-6.9	med. stiff CLAY LOAM	A-6					alluvium
					6.9-8.0	med. stiff SILTY CLAY LOAM	A-7-6(26)		46	21	25	
22	SR 46	906+00	20L	617.0	0-.7	topsoil						alluvium
					.7-2.2	med. stiff CLAY LOAM	A-6					
					2.2-4.4	med. stiff to soft SILTY CLAY	A-7-6					
					4.4-6.3	loose SANDY LOAM	A-2-4					
					6.3-8.0	med. dense SAND	A-1-6					
23	SR 46	915+00	2R	616.0	0-6.1	stiff to med. stiff SILTY CLAY	A-7-6	14,6				alluvium
					6.1-8.5	loose SAND	A-1-6	7				
					8.5-10.0	med. dense GRA & SAND	A-1-6	13				
24	SR 46	930+50	25R	613.0	0-7.0	med. stiff CLAY LOAM	A-6	10,7,7				alluvium
					7.0-9.5	soft SILTY CLAY	A-7-6	5				
					9.5-13.3	very soft SILTY CLAY LOAM		2				
					13.3-15.0	loose SAND	A-1-6	9				
					15.0-16.5	med. dense GRA & SAND	A-1-6	11				
25	SR 46	934+00	25R	613.8	0-6.0	med. to v.stiff CLAY LOAM	A-6	17,7				alluvium
					6.0-12.5	loose SAND	A-1-6(0)	7,7,7				
26	SR 46	60+00	19R	613.0	0-6.0	stiff CLAY LOAM	A-6					alluvium
27	SR 46	66+50	20L	622.0	0-2.5	roadfill						alluvium
					2.5-7	med. dense SANDY LOAM	A-2-4					
					7-8.5	stiff CLAY LOAM	A-6					
					8.5-10	dense SANDY LOAM	A-2-4					
						STATE ROAD 9 [26].						
28	SR 9	151+60	15R	674.0	0-2	fill						Wisconsinan ground moraine
					2-5	med. stiff CLAY	A-7-6		48	19	29	
					5-6	med. stiff CLAY	A-6(11-16)					

APPENDIX A (cont.)

Borehole Number	Highway Route	Station	Offset	Surface Elevation	Depth	Soil Description		SPT*	LL	PL	PI	Notes
						Texture	AASHO					
		feet	feet		feet			blows/foot	%	%	%	
29	SR 9	221+50	10L	681.0	0-2	med. stiff SILTY CLAY	A-4(5-8)					Wisconsinan ground moraine
					2-4	stiff CLAY & tra gra	A-7-6(12-20)					
					4-8	stiff CLAY LOAM & tra gra	A-4(5-8)					
30	SR 9	225+20	13L	688.7	0-1	topsoil						Wisconsinan ground moraine
					1-4	stiff CLAY	A-7-6(16-20)					
					4-6	med. stiff CLAY	A-6(11)		35	15	20	
31	SR 31A	229+00	13R	706.5	0-1	fill						
					1-2	med. stiff SILTY CLAY LOAM	A-4(8)		30	20	10	Wisconsinan ground moraine
					2-4	stiff CLAY	A-7-6(16-20)					
					4-8	stiff CLAY LOAM	A-4(5-8)					
32	SR 31A	238+00	10L	695.7	0-0.5	fill						
					0.5-4	med. stiff CLAY & little gra	A-7-6(16-20)					
					4-6	stiff CLAY LOAM & little gra	A-4(5-8)					Wisconsinan ground moraine
					6-8	med. stiff SANDY CLAY LOAM	A-6(0-10)					
					8-11	med. stiff LOAM	A-4(6)		22	17	5	
BRIDGE ON STATE ROAD 7 [21].												
33	SR 7	866+55	37L	620.5	0-5.0	stiff to v. stiff LOAM & tra gra		8,16				
					5.0-9.5	stiff LOAM & tra wood	A-6(7)	12,13	33	18	15	W_n = 15.2, pH = 7.1
					9.5-20.0	med. stiff LOAM	A-6(6)	6,16	28	16	12	W_n = 15.6, pH = 6.9, q_u = .22, .49, .61, and .68 tsf at 15 ft.
					20.0-32.5	med. stiff CLAY LOAM	A-6(11)	10,9,10	35	14	21	W_n = 18.8, pH = 7.0
					32.5-46.4	med. dense SAND	A-1-6(0)	14,15,9				
					46.4-55.6	dense SAND & GRA	A-7-6(22)	37,17				
					55.6-57.0	soft to v. stiff CLAY w/ tra gra			49	18	31	W_n = 32.7, pH = 7.0
					57.0-62.2	gray fossiliferous LIMESTONE						RQD = 87%
BRIDGE OVER COUNTY ROAD 500 E [27].												
34	CR 500E	6+93	8R	646.4	0-3.0	v. loose SANDY LOAM fill		3				alluvium
					3.0-7.5	med. stiff SILTY CLAY	A-6	8,7				sand and gravel outwash
					7.5-18.5	loose SAND	A-2-4(0)	6,9				
					18.5-24.0	med. dense SAND	A-2-4	11				
					24.0-31.0	med. dense GRAVELY SAND	A-2-4	22,24				
					31.0-39.5	med. dense SANDY GRA		11				

APPENDIX A (cont.)

Borehole Number	Highway Route	Station	Offset	Surface Elevation	Depth	Soil Description		SPT*	LL	PL	PI	Notes
						Texture	AASHO					
		feet	feet		feet			blows/foot	%	%	%	
					39.5-43.0	stiff SILTY CLAY	A-6	11				Wisconsinan or
					43.0-54.0	stiff to hard CLAY LOAM	A-4	12,50/.4'	24	21	3	Illinoian ground moraine
					54.0-59.0	hard vuggy LIMESTONE						RQD = 12%
WELL RECORDS, INDIANA GEOLOGICAL SURVEY [17].												
35				641	0-16	CLAY						
					16-22	SAND, soupy						Illinoian
					22-53	CLAY						ground
					53-57	SAND						moraine
					57-64	CLAY						
					64-69	SAND						
					69-140	SHALE						New Albany shale
					140-198	LIMESTONE & DOLOMITE						Jeffersonville lm.
					198-214	DOLOMITE						Geneva dolomite
					214-239	DOLOMITE						Waldron shale
					239-309	LIMESTONE						Laurel limestone
36				675	0-2	soil						Illinoian
					2-12	hardpan						ground
					12-18	soft CLAY						moraine
					18-25	wet CLAY						
					25-27	CLAY						
						black & brown SHALE						New Providence sh.
37					0-5	SANDY CLAYEY TILL						Wisconsinan
					5-20	SILTY SANDY TILL						ground moraine
					20-23	CLAYEY TILL						Illinoian
					23-30	CLAYEY TILL						ground moraine
					30-33	SHALE						New Albany sh.
					33-36	coarsely crystaline LIMESTONE						North Vernon lm.
					36-81	LIMESTONE & DOLOMITE						Jeffersonville lm.
					81-112	DOLOMITE						Geneva dolomite
					112-116	LIMESTONE						Louisville lm.
PIPE ARCH STRUCTURES ON STATE ROAD 58 [28].												
38	SR 58	1196+02	25R	646.8	0-1.0	topsoil						
					1.0-3.0	med. stiff SILTY LOAM	A-6	7				
					3-20	stiff to v. stiff CLAY	A-7-6	9,10,11,16, 25				till at 17 feet
39	SR 58	1312+03	40L	599.5	0-3	v. loose SILTY LOAM	A-4(0)	4				alluvium
					3-6.5	soft SILTY LOAM	A-4(5)	5				lacustrine
					6.5-27.5	soft to med. stiff LOAM w/tra organic and few sand & gra seams	A-6	4,9,10.5				soil

APPENDIX A (cont.)

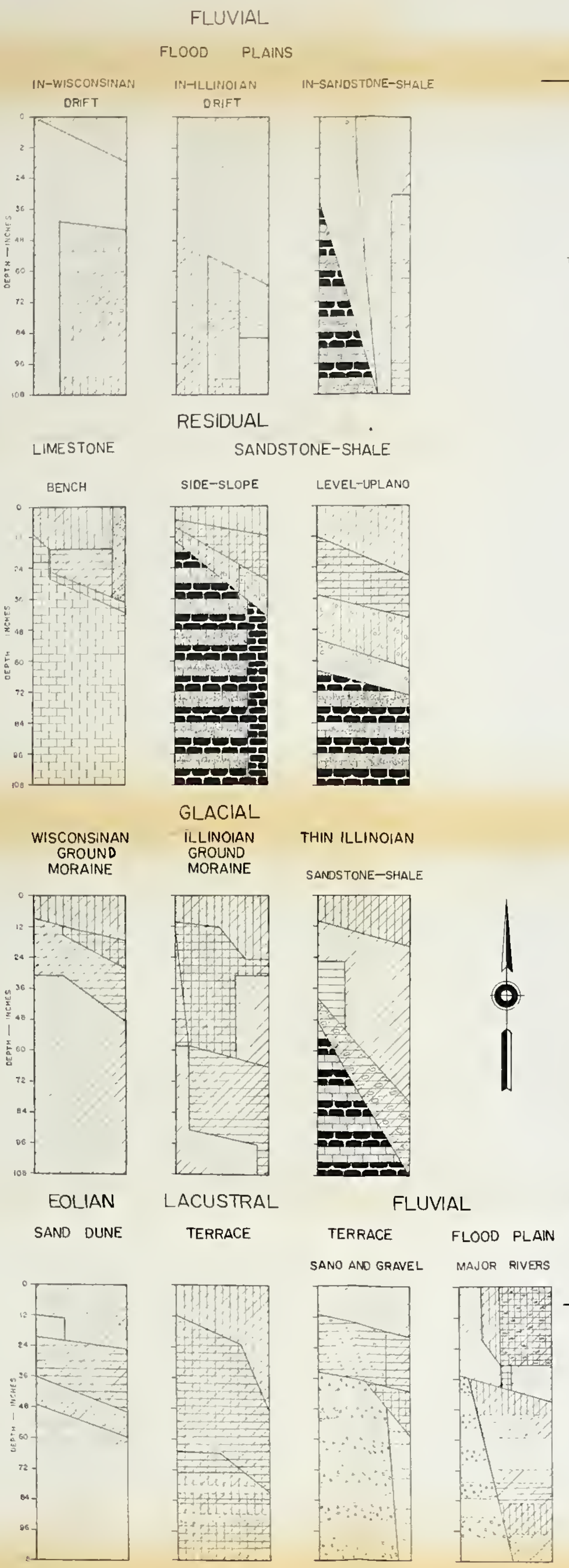
Borehole Number	Highway Route	Station	Offset	Surface Elevation	Depth	Soil Description		SPT*	LL	PL	PI	Notes
						Texture	AASHO					
		feet	feet		feet			blows/foot	%	%	%	
					27.5-30.0	med. dense SAND		18				
40	SR58	1312+02	31R	603.2	0-5.5	med. stiff to v. soft SILT	A-4(7)	6,2				}alluvium
					5.5-13.0	stiff silty LOAM	A-4	9,12,12				lacustrine
					13.0-18.5	v. loose SANDY LOAM	A-2-4(0)	4				soil
					18.5-23.0	med. stiff CLAY LOAM	A-7-6	6				
					23.0-27.0	v. dense LOAM w/some gra	A-2-4(0)	62				
					27.0-29.8	stiff SILTY CLAY	A-6(17)	12				
					29.8-35.0	dense SAND	A-2-4(0)	44				
41	SR 58	1449+32.5	17L	610.5	0-3.0	v. soft SILTY LOAM	A-6	3				}alluvium or loess
					3.0-8.0	soft to stiff LOAM	A-4(1)	4,15				}Ill. grd. moraine
					8.0-10.0	soft weathered SHALE		21				}New Providence sh.
42	SR58	1449+28.5	17R	610.2	0-2.5	soft SILT		4				}alluvium
					2.5-5.5	med. stiff SILTY LOAM	A-6	6				lacustrine soil
					5.5-10.0	soft v. weathered SHALE		18,49				New Providence sh.
43	SR 58	1655+42	21L	636.6	0-4.0	v. soft SILT	A-4	2				}alluvium or loess
					4.0-6.0	med. stiff SILTY LOAM	A-6	10				Illinoian
					6.0-10.0	hard LOAM	A-4(2)	68,51				ground moraine
44	SR 58	1655+15	29R	636.6	0-6.5	v. soft SILT	A-4	3,2				}alluvium or loess
					6.5-12.0	med. stiff SILTY LOAM	A-4	8,29				Illinoian
					12.0-15.0	stiff SILTY LOAM	A-6	12				ground moraine
45	SR 58	12+99	22.5L	636.7	0-4.0	v. soft SILTY LOAM	A-6	3				}alluvium or loess
					4.0-5.5	med. dense SANDY LOAM	A-2-4	18				Illinoian
					5.5-10.0	hard LOAM	A-4	88,46				ground moraine
46	SR 58	13+16	20R	637.6	0-5.5	v. soft to soft SILT	A-4	2,4				}alluvium or loess
					5.5-10.0	hard LOAM	A-4	44,44				Ill. grd. moraine

APPENDIX A (cont.)

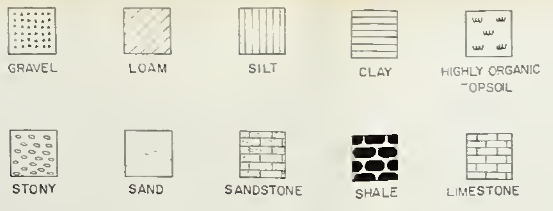
JHPP-86/6

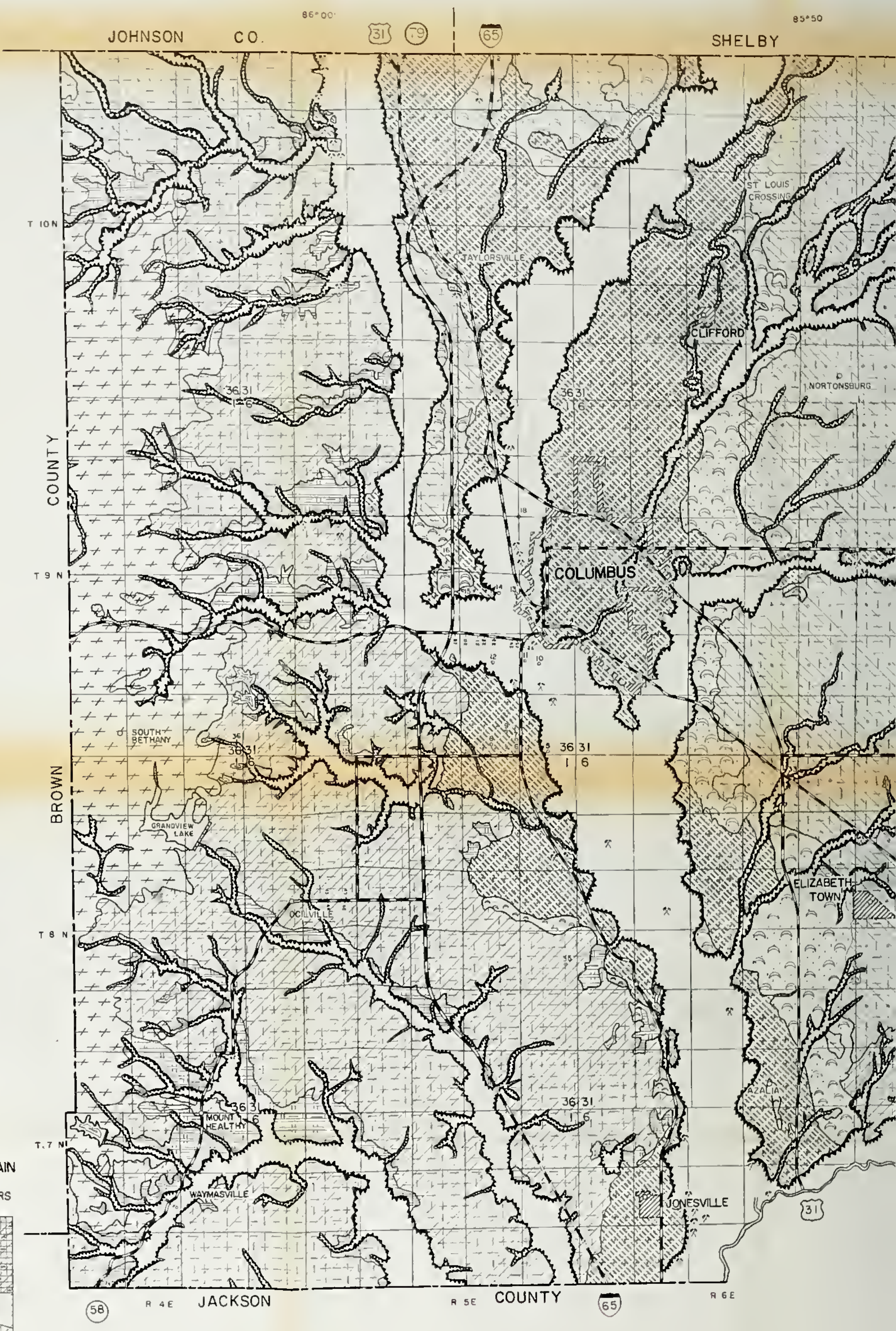
JHRP-86/6

GENERAL SOIL PROFILES



TEXTURAL SYMBOLS FOR SOIL PROFILES

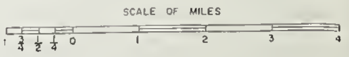




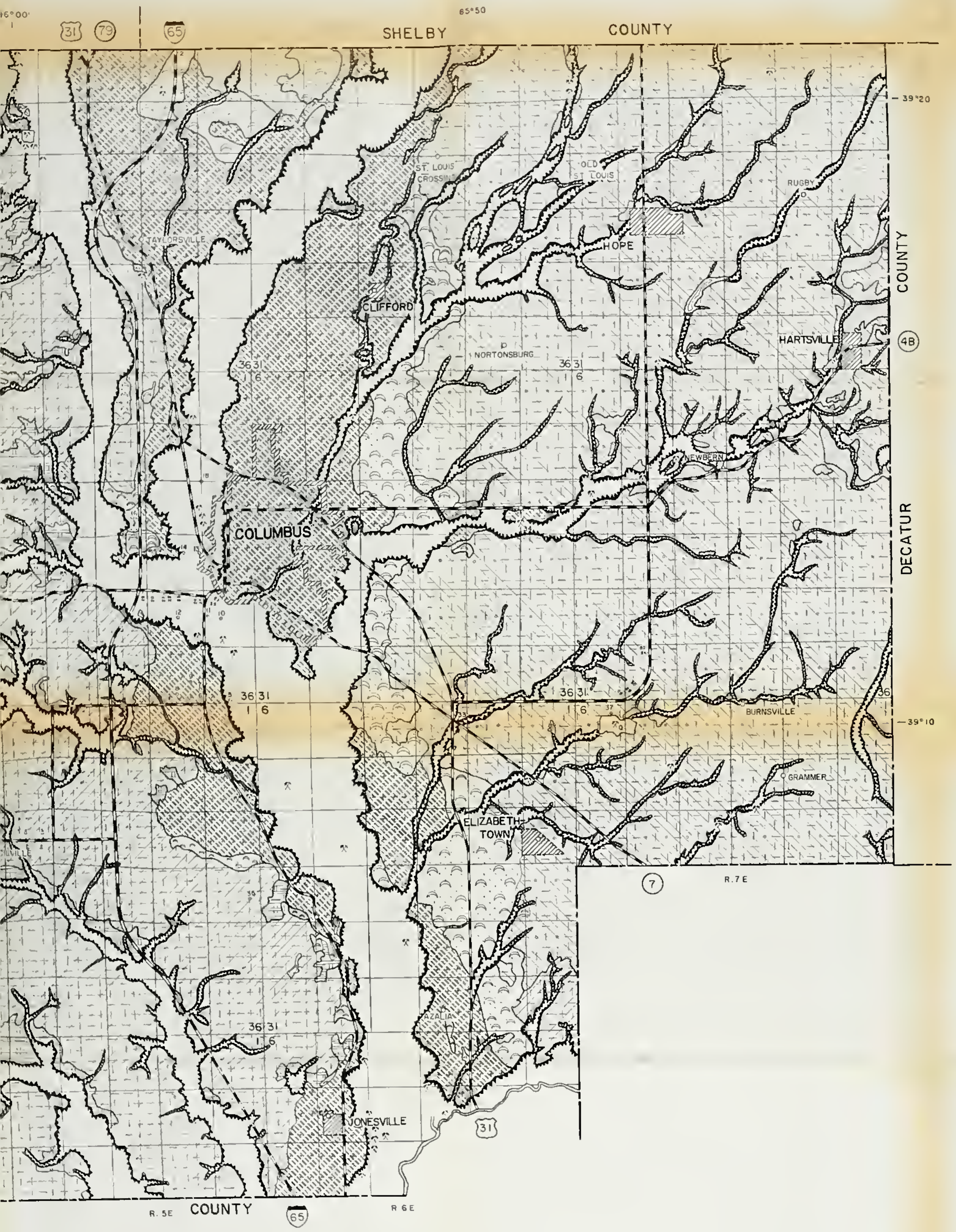
ENGINEERING SOILS MAP
BARTHOLOMEW COUNTY
INDIANA

PREPARED FROM
AERIAL PHOTOGRAPHS
BY
JOINT HIGHWAY RESEARCH PROJECT
AT
PURDUE UNIVERSITY

1985



PREPARED UNDER THE SUPERVISION OF JOHN L TYREE AND R D MILES



ENGINEERING SOILS MAP

BARTHOLOMEW COUNTY

INDIANA

PREPARED FROM
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AT
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1985

SCALE OF MILES
1 3/4 1/2 1/4 0 1 2 3 4

LEGEND

PARENT MATERIALS
(GROUPED ACCORDING TO LAND FORM AND ORIGIN)

- GROUND MORAINE, ILLINOIAN
- GROUND MORAINE, WISCONSINAN
- THIN ILLINOIAN DRIFT OVER INTERBEDDED SANDSTONE AND SHALE
- SANDSTONE—SHALE PLATEAU
- OUTWASH TERRACE
- LACUSTRAL TERRACE
- SAND DUNE
- LIMESTONE BENCH
- FLOOD PLAIN

MISCELLANEOUS

- BORING SITES
- URBAN AREA
- LAKE, POND, OR RESERVOIR
- DAM
- GRAVEL PIT
- QUARRY

TEXTURAL SYMBOLS

SUPERIMPOSED ON PARENT MATERIAL TO SHOW RELATIVE COMPOSITION

- GRAVEL
- SILT
- SAND
- CLAY

DRAWN BY XIAOGONG WANG

COVER DESIGN BY ALDO GIORGINI